NEW

GADGETS & FUTURE TECH LIFESTYLE ENGINEERING BIOTECH

The rise of the bionic man

Say hello to JIBO

The uses of drones

COVERS ALL THE LATEST TECH

The first hoverboard

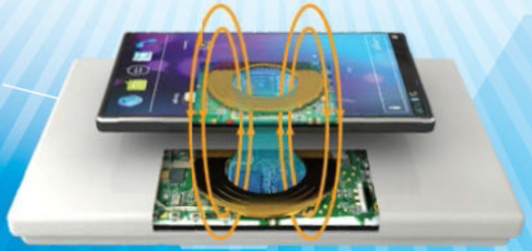
Inisde the Tesla Model S

HOW IT WORKS BOOK OF AMAZING TECHNOLOGY

Vol.4

EVERYTHING YOU NEED TO KNOW ABOUT THE WORLD'S BEST TECH

Get inside virtual reality


Unweaving wireless chargers

Introducing domestic robots

Extreme luxury cruises

The future of cinema

WELCOME TO

HOW IT WORKS
BOOK OF
AMAZING TECHNOLOGY
Vol. 4

Today's world is driven by technology. It's changed the way we communicate over mobile phones and the Internet, the way we travel in hybrid cars and on hoverboards, the way we build high skyscrapers and underground metro systems, and the way we treat patients and investigate crimes. The newest developments in technology change the way we live, but few of us actually understand the inner workings of our most sophistacted gadgets and machines. With this fourth volume of The How It Works Book of Amazing Technology, we aim to answer the questions behind today's technology, from small appliances like a drill, to huge and intangible concepts like cloud computing. Get closer to understanding our world, and start reading!

AMAZING TECHNOLOGY Vol.4

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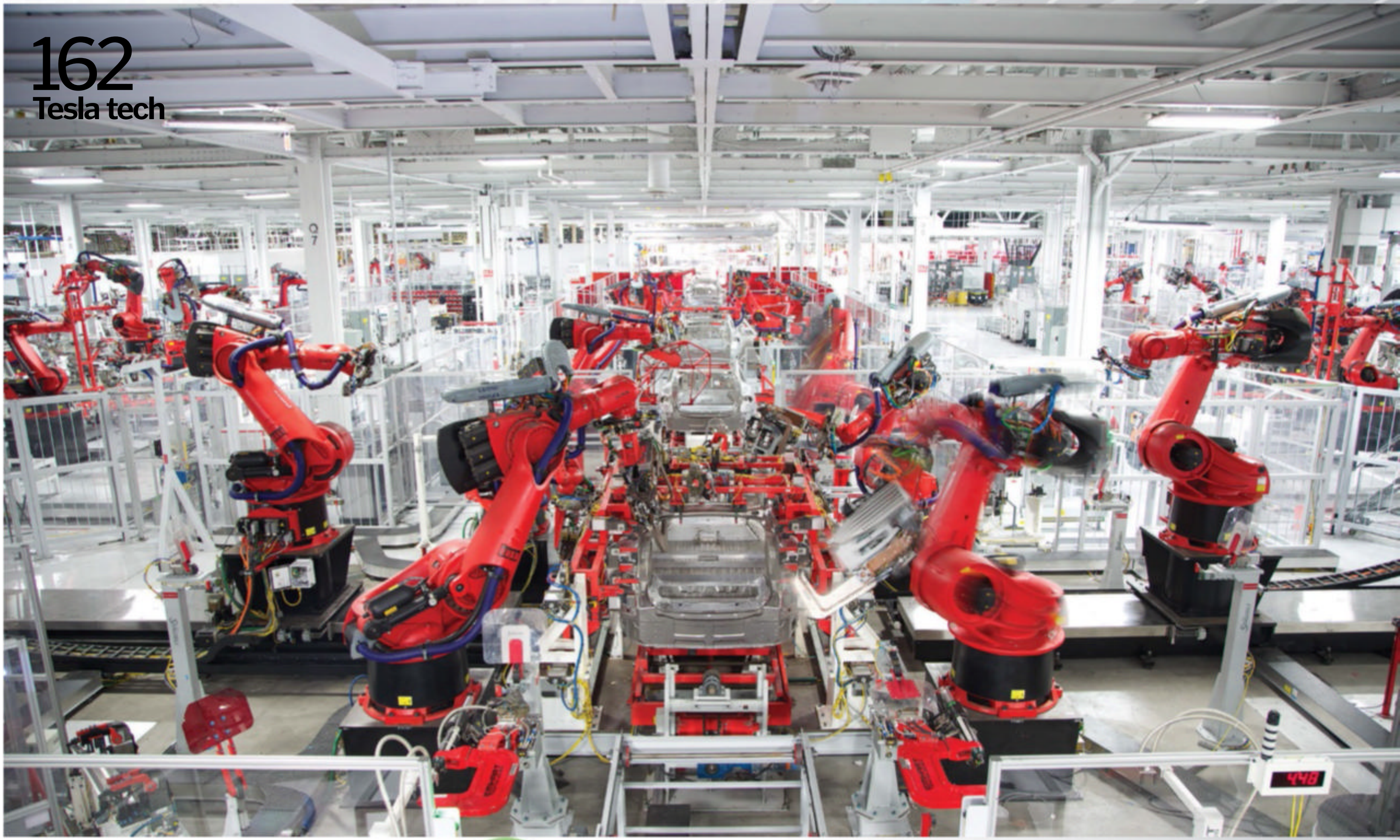

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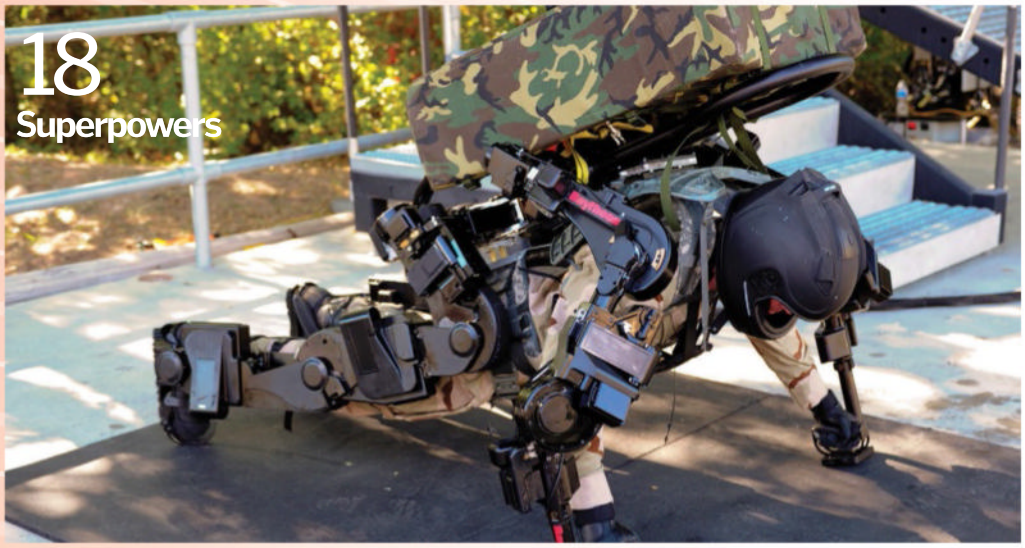
GADGETS & FUTURE TECH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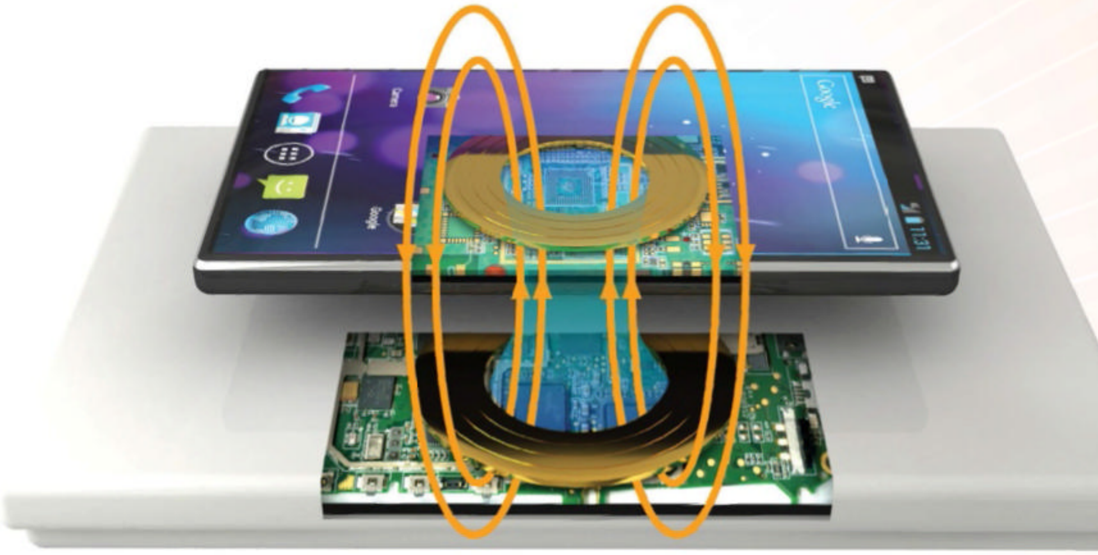

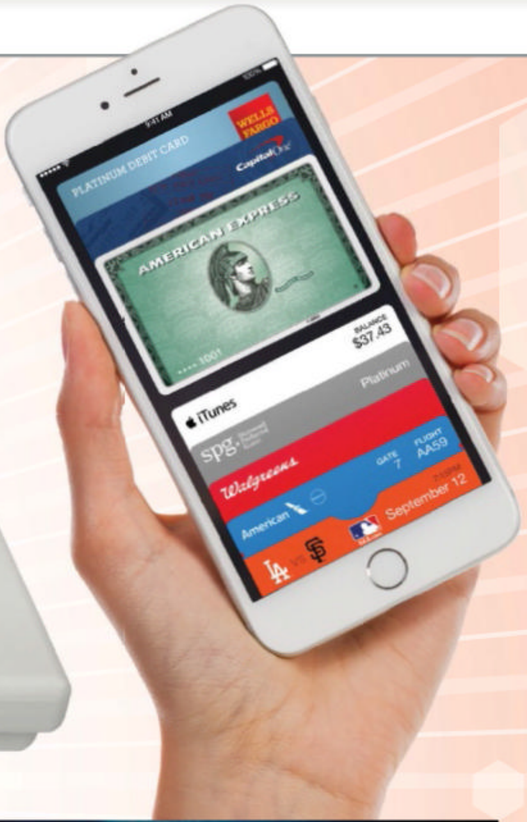

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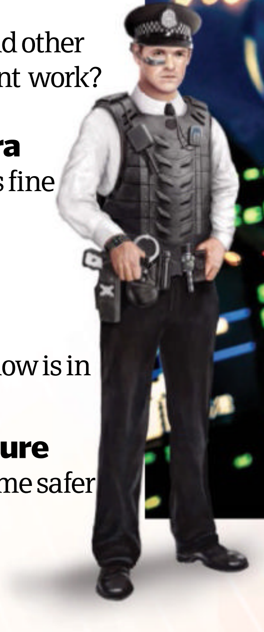

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CRIME FIGHTING TECH

THE COOL COP GADGETS THAT ARE WAGING A WAR ON VILLAINY

Throwable robotic cameras and high-speed drones are just a few of the revolutionary crime-fighting technologies on the horizon. The development of this advanced equipment has become crucial to helping police officers investigate and solve cases in the face of severe budget cuts. In the UK alone, the police have had their funds slashed by 20 per cent in the last four years. On top of that, there are now only 43 police forces in the UK compared to 120 in 1946.

Police chiefs around the world are unlikely to be getting more officers or more money in the near future, yet investments in new technology are still being made in almost every department, in the hope that it will improve the speed and accuracy of their work. These innovations hold the key to cutting costs and reducing the need for a physical police presence.

One innovative piece of crime-fighting tech is ShotSpotter, a gunshot detection system that's becoming commonplace in the United States. It's made up of a series of microphones that detect gunfire based on an algorithm. If a shot is fired, an alert is sent to police headquarters.

Officers are also utilising a new type of software in order to predict and prevent crime in their communities. Known as PredPol, it works by using only three bits of data to forecast felonies: the previous types of crime committed in an area, the precise location and the time of day. This software is an invaluable tool for the police branches that use it, helping officers to optimise their time and help stop crime before it happens.

It is believed that just by having a police presence in these identified areas, crimes are less likely to occur. The Los Angeles Police Department has had great success with PredPol so far, and claim to disrupt criminal activity eight to ten times a week as a result.

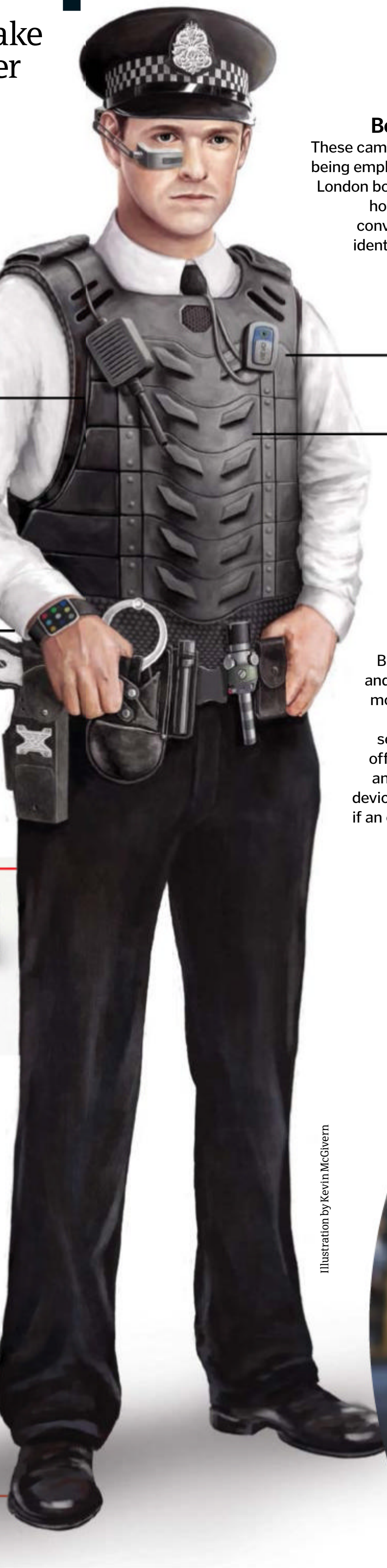
As criminals become wiser to police practices, smart technology will become paramount. Facial recognition, laser-mapping and secure police apps have all been significant additions to police forces around the world, and are now relied upon extensively.

We aren't close to pre-arresting criminals like Tom Cruise in *Minority Report* or seeing a superhuman cyborg law enforcer in the style of *RoboCop*, but we will see police forces armed with more hi-tech tools in the years to come.

DID YOU KNOW? *In Thailand, misbehaving police officers are forced to wear a pink Hello Kitty armband as a punishment*

Future cops

The gadgets that will make officers safer and smarter



Graphene protection
Supermaterial graphene could be used to make tough yet light body armour. It is 200 times stronger than steel but weighs six times less.

Body camera
These cameras are already being employed across ten London boroughs, and are hoped to speed up convictions and also identify bad policing.

Smart watch
Wearable tech such as smart watches can provide officers with quicker access to intelligence, including photos or tweets posted in their location.

Smart vest
Built-in heart rate and blood pressure monitors can alert the emergency services when an officer needs help, and there's even a device that identifies if an officer falls or is knocked over.

Taser
Not every officer in the UK carries one but they are commonplace in the United States, stopping suspects by delivering a high-voltage shock.

Illustration by Kevin McGivern

The non-lethal laser dazzler

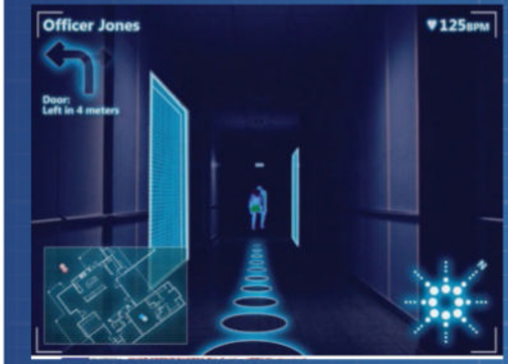
The Dazzler does much more than temporarily blind bad guys: it can also stop them in their tracks. Developed by Intelligent Optical Systems Inc for the Department of Homeland Security in the United States, this flashlight measures the distance to the target's eyes with a range finder, so that it can adjust the strength of the light pulses it fires to ensure that no permanent damage is done. These ultrabright light emitting diodes (LEDs) incapacitate a person in two ways. The flashes cause temporary blindness like any strong light does, but the real innovation lies in the psychophysical effects, ranging from vertigo to disorientation to nausea, typically lasting for a few minutes.

The real-life RoboCop headset

Golden-i is a new wearable headset that provides police officers with superhuman abilities. The Golden-i gives the wearer access to important information quickly and easily, and is operated by voice commands and head movements, leaving the officer's hands free. It provides real-time situational awareness by accessing nearby CCTV and live video feeds from other headsets in the area.

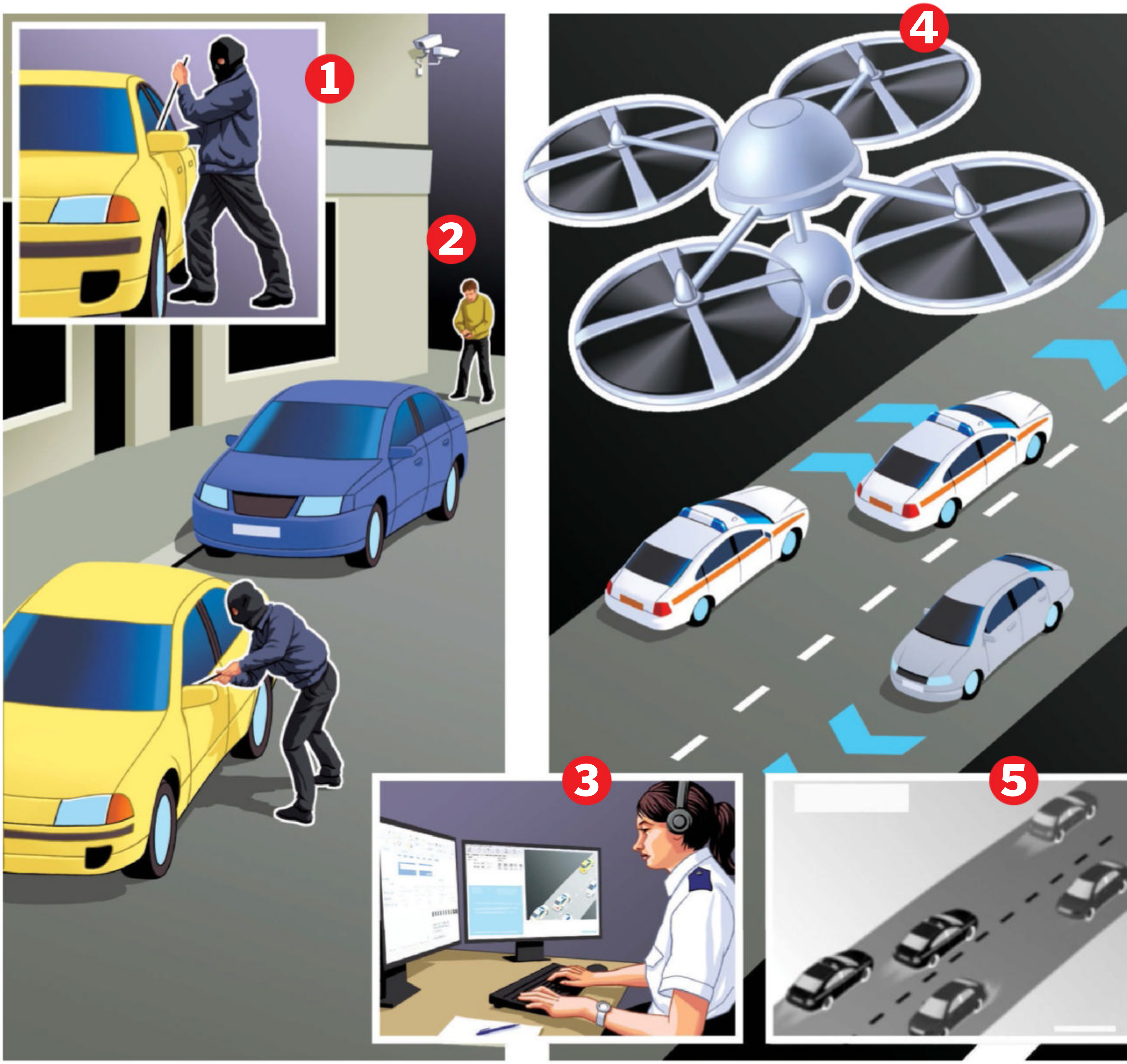
The accompanying Police Pro application has facial recognition software to identify suspects already known to the police, and can call up floor plans and GPS coordinates of places of interest. Most impressive of all is its ability to see through walls using infrared technology, great for finding a hiding suspect when combined with its thermal vision application.

The Golden-i's 14-megapixel camera is inertially stabilised, allowing even a running police officer to record smooth video of a crime in progress. Slightly different versions of Golden-i have also been designed for firefighters and paramedics.



The heat sensor function helps to find hidden suspects when visibility is poor

© Golden-i/Rex Features; Thinkstock



Catching criminals

See the latest tech in action, and how it can help to make an arrest

1 CCTV

It is estimated that there are nearly six million CCTV cameras in Britain – about one camera for every ten people – making it one of the most heavily-surveilled countries in the world. The police have access to all CCTV cameras, and can often find vital video evidence that can be used in court.

2 Social media

The relatively recent social media boom has not gone unnoticed by the police. They have their own intricate software that scans all social media channels for key words related to crimes they are investigating, and use it to pinpoint times and locations of specific offences. You'd be amazed at how many people incriminate themselves on Facebook.

3 Police HQ

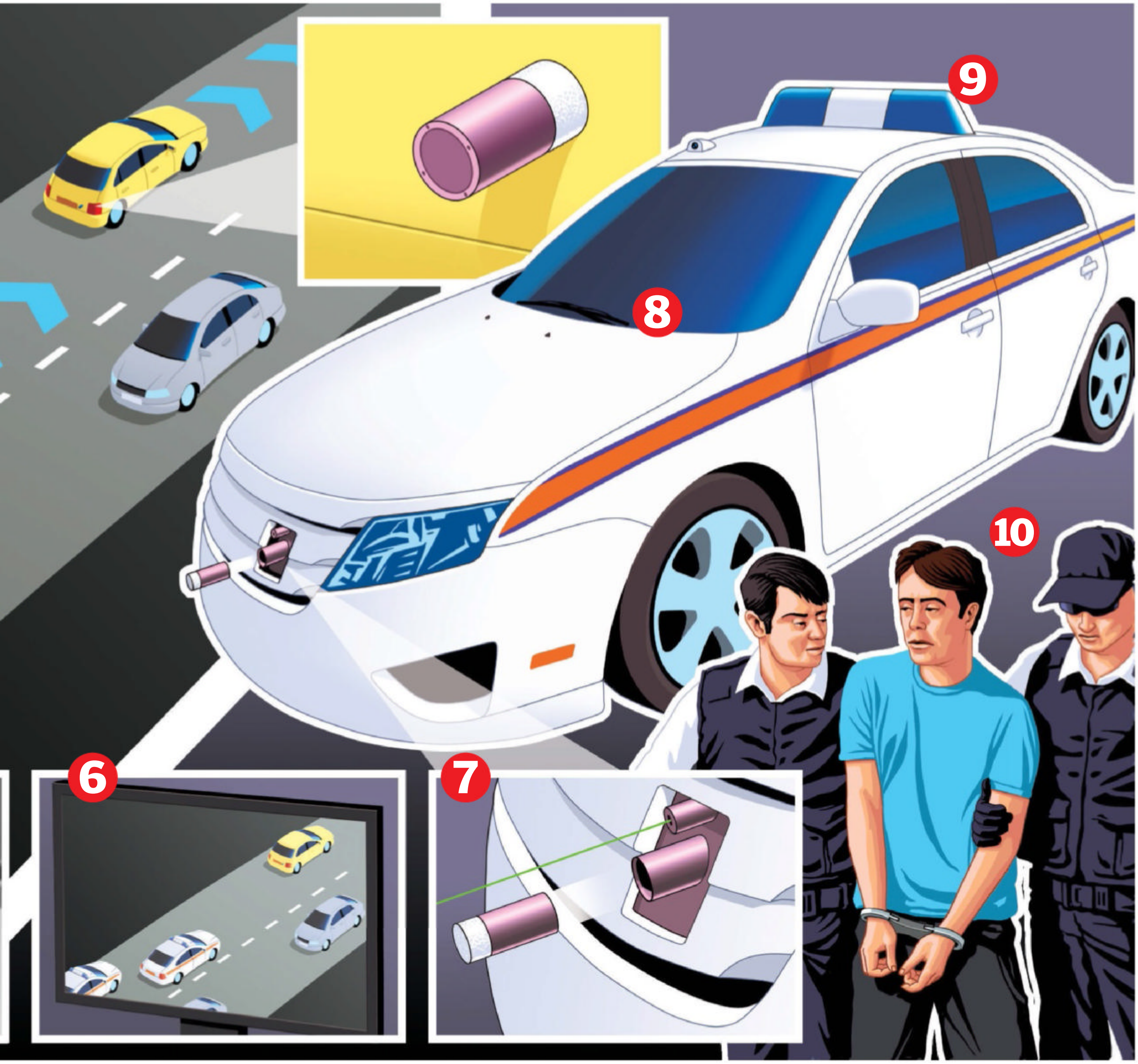
Police headquarters collate all the available information so they can decide on the most appropriate response. They will also receive emergency calls from the general public that they must respond to as quickly as possible, often by requesting a police presence at the area in question.

4 Drone surveillance

Police surveillance drones can be controlled remotely by officers, allowing them to follow a fleeing suspect without risking injury to themselves. Modern drones can stream live video either to police cars or headquarters, so that the suspect's location and activity can be monitored in real time.

5 Thermal imaging

For police patrolling at night, visibility is always an issue. Thermal-imaging cameras give officers the night-vision edge of a police helicopter, perfect for finding a suspect hiding under the cover of night. Advanced systems can see a full 360 degrees around the vehicle due to their pan and tilt functions.



6 OnStar remote deactivation

A new subscription service called OnStar has the ability to track your car if it's stolen, and can even remotely disable the vehicle by shutting down its engine. This was used recently in the United States to catch a car thief. The police hope that it will reduce the need for high-speed police chases in the future, which are often very dangerous and costly.

7 GPS dart

The GPS dart system is a new concept for police cars around the world. This laser targeting device fires a small, mobile phone-sized GPS tracker, which sticks to cars thanks to its strong adhesive coating. This enables the police to remotely monitor the vehicle's route, and plan how they want to apprehend the suspect.

8 Licence plate cameras

Automated licence plate scanners are being fitted to more and more police cars. They record licence plate information for every car they see (they can scan thousands of plates per hour) and feed this into the onboard computer to see if any of the cars are of interest to the police.

9 Super sirens

The need for improved sirens has prompted many police forces to try a new, more powerful siren system, which can alert drivers that are playing loud music in their own vehicles. Large woofers by the wheels produce a deeper sound that can be heard up to 61 metres (200 feet) away.

10 Hi-tech handcuffs

Although somewhat sinister, hi-tech handcuffs are being pushed for by many police forces. Unlike the simple steel restraints currently available, they have the ability to deliver taser-like shocks to prisoners if they fail to comply with police orders or suddenly become aggressive.

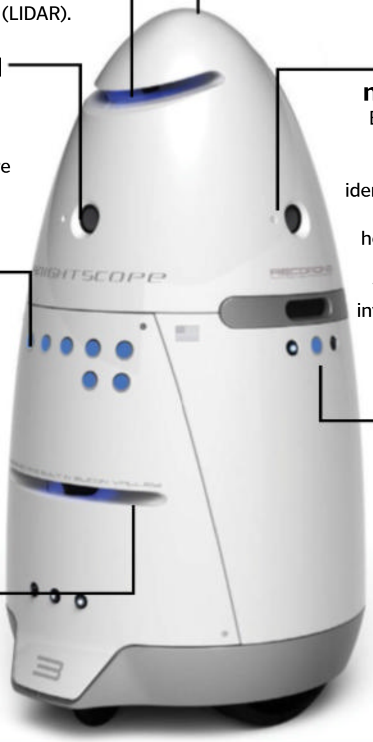
Illustration by Tom Connell

K5 crime-fighting robot

Will this Dalek-like machine change the way our cities are policed?

Meet the Knightscope K5, the world's first security 'bot that its inventors believe can cut crime by 50 per cent in the areas it patrols. The K5 stands at just over 1.5 metres (five feet) tall and is fitted with an array of technology, from number plate recognition to thermal imaging. It even has odour detectors that can monitor pollution.

The K5 is designed to be fully autonomous, patrolling and charging itself without any human involvement. In spite of its ominous appearance it is not weaponised, mainly working towards crime prevention and serving as an extra source of intelligence for the police. The K5 will initially be used as part of campus security, either for universities or businesses that occupy large sites. However, there is no reason why these clever robots won't eventually make their way onto our streets.



LIDAR
The K5 can measure distance and 3D-map areas by illuminating a target with a laser and then analysing the reflected light, a technology known as Light Image Detection and Ranging (LIDAR).

Emergency button
An emergency button on the K5 allows passers-by to push and talk immediately to the emergency services.

Multi-directional imaging
Its high definition, 360-degree camera allows the K5 to capture video in all directions.

Sensitive microphones
By using its audio event detection software, the K5 identifies significant sounds such as horns honking and glass smashing, which it can then investigate further.

Character recognition
By scanning the images its camera takes and converting the text into code, the K5 can search a defined database for key crime terms.

Powerful lights
30 LEDs and six infrared lights give the K5 excellent illumination, helping it see clearly in poor light.

Accurate GPS
The K5's GPS is accurate to 2.5 metres (8.2 feet) and can be detected in less than one second.

Crime scene drones

Few would argue with the fact that understanding the crime scene is key to solving any offence. This usually requires a crime scene investigator to take extensive photographs, which can be a lengthy process that risks contamination and even the destruction of evidence. By sending in a drone, however, the entire scene can be photographed without disturbance in just 15 minutes.

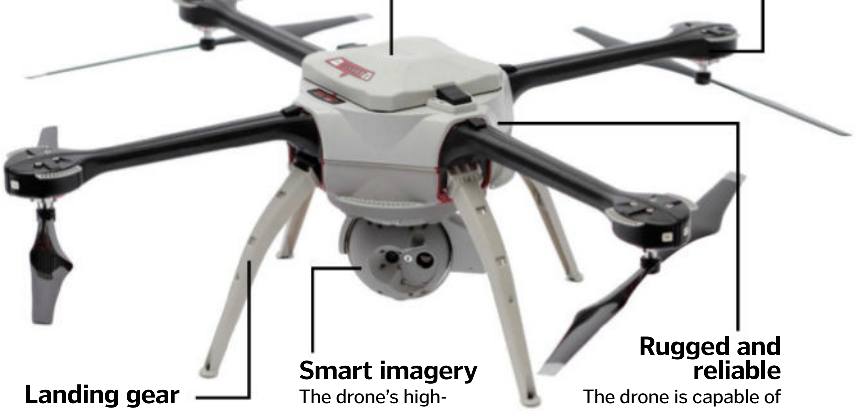
These images can then be used to build up a three-dimensional model of the scene, which can be examined back at police headquarters immediately and even submitted in court as evidence. High-resolution photography of fingerprints can be quickly uploaded to databases and compared with police records. This could potentially identify a criminal without officers having to step foot onto the scene.

A drone can also capture video, quickly identifying points of interest that crime scene investigators can examine further. Dangerous crime scenes that forensic teams wouldn't dare enter become accessible, and these autonomous machines can fly in and detail the evidence before it is damaged further by any adverse building conditions.

However, as much as drones can provide an invaluable crime-fighting service, their use must be carefully monitored to avoid invasions of privacy and general misuse. Weaponised police drones won't be permitted in many parts of the world, although there has been a law passed in North Dakota in the United States to allow police to fire tasers from drones. The potential uses of drones are vast, but we are yet to see how much the police will utilise them.

Aeryon SkyRanger

Find out why the Aeryon SkyRanger is the go-to drone for police around the world



Airborne in seconds
Its folding design allows the drone to be stored in a backpack when not in use, and can be quickly prepared for flight without the need for extra assembly.

Power plant
The top-mounted battery unit powers four motors, allowing the drone to fly continuously for up to 50 minutes.

Landing gear
The four flexible legs help the drone survive hard landings, protecting the camera and electronics from damage.

Smart imagery
The drone's high-resolution camera can stream HD video to police headquarters and capture 15-megapixel still images.

Rugged and reliable
The drone is capable of withstanding winds of 65km/h (40mph) and temperatures of -33 to 50°C (-27.4 to 122°F).

1901
Human blood grouping (ABO) is discovered by Karl Landsteiner. This system is later adopted for use on crime scene bloodstain analysis.

1910
Edmond Locard, a pioneer of forensic science, opens the first official police crime lab in Lyon, France.

1930s
Cars and motorbikes start to be used regularly by the police.

1932
The FBI establishes its Technical Laboratory, providing forensic support.

1960s
Auditory analysis is used to identify speakers from recordings by comparing their 'voiceprints'.

DID YOU KNOW? *In the UK, fingerprint evidence was first used in 1902 to convict burglar Harry Jackson*

Snapshot facial reconstruction

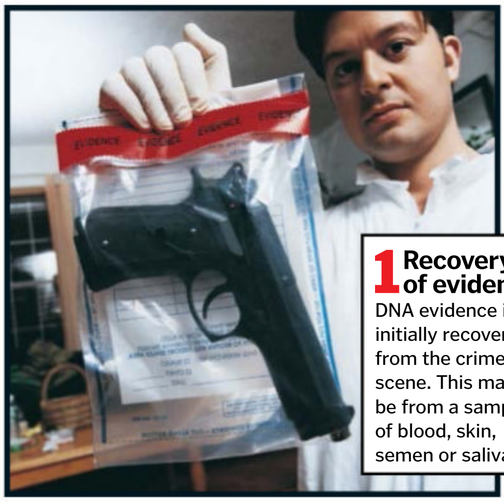
This incredible system can create a face from nothing more than genetic code

Various methods for facial reconstruction have existed for decades, but none are as impressive as Snapshot DNA phenotyping. This technique can be used in the absence of photographic or video evidence, and can create a prediction of what a suspect's face looks like just using a sample of their DNA. It determines skin, hair and eye colour, as well as face shape and detailed biogeoprahic ancestry.

When the police have nothing else to go on this information is invaluable, and can quickly narrow down a list of suspects. Hopefully, as our understanding of DNA improves it will be possible to pick out further characteristics, which will allow even more detailed facial reconstructions to be created.

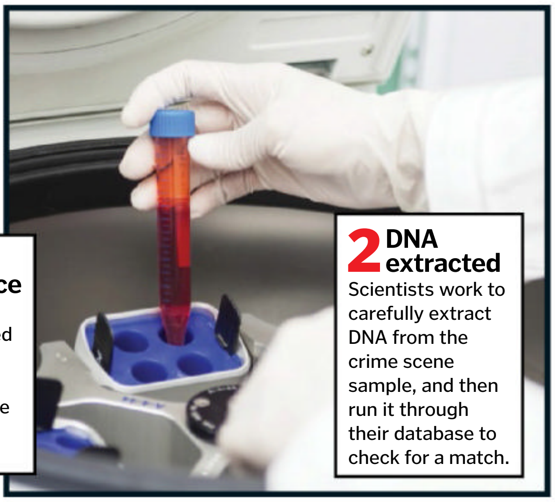
CRIME SCENE DO NOT CROS

Samples of DNA found at a crime scene can be used to establish a rough idea of the perpetrator's appearance


EVIDENCE
EVIDENCE
EVIDENCE

1 Recovery of evidence

DNA evidence is initially recovered from the crime scene. This may be from a sample of blood, skin, semen or saliva.

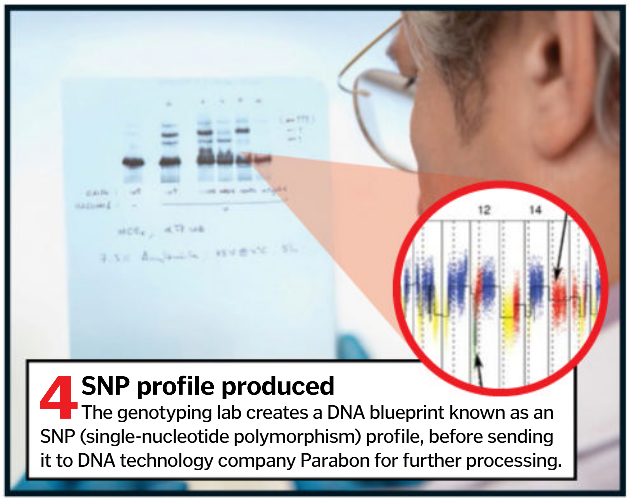


2 DNA extracted

Scientists work to carefully extract DNA from the crime scene sample, and then run it through their database to check for a match.

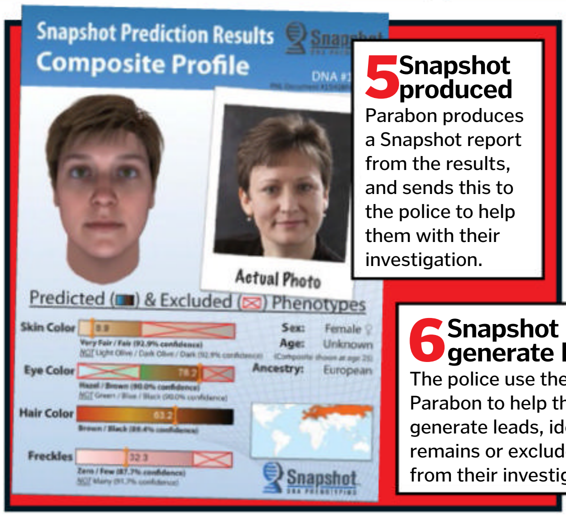
3 Match found?

If a match on the database is found, an arrest can be made. If not, the sample is sent to be analysed.



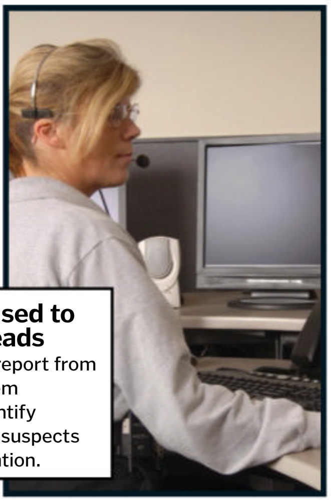
4 SNP profile produced

The genotyping lab creates a DNA blueprint known as an SNP (single-nucleotide polymorphism) profile, before sending it to DNA technology company Parabon for further processing.


Snapshot Prediction Results
Composite Profile
Snapshot
DNA #
Actual Photo
Predicted (▬) & Excluded (☒) Phenotypes
Skin Color
Very Fair / Fair (92.9% confidence)
Eye Color
78.2
Hazel / Brown (90.0% confidence)
Hair Color
63.2
Brown / Black (89.4% confidence)
Freckles
32.3
Zero / Few (87.7% confidence)
Sex: Female
Age: Unknown
Ancestry: European
Snapshot

5 Snapshot produced

Parabon produces a Snapshot report from the results, and sends this to the police to help them with their investigation.



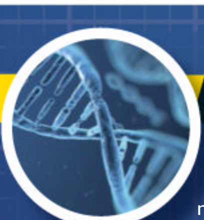
6 Snapshot used to generate leads

The police use the report from Parabon to help them generate leads, identify remains or exclude suspects from their investigation.

© Rex; Knightscope, Inc.; Thinkstock; Alamy

1985
The Home Office Large Major Enquiry System (HOLMES) is established, using computer systems to support major investigations.

1988
Colin Pitchfork becomes the first person to be convicted of murder on the basis of DNA evidence.



1995
The UK sets up a national DNA database, which contains samples from crime scenes, potential suspects and detainees.

2004
Police forces in England and Wales have access to tasers, although only specially trained officers are allowed to use them.

2020?
It is hoped that advancements in nanotechnology will lead to the development of new forensic techniques, helping to speed up DNA analysis.

Inside the Google Cardboard

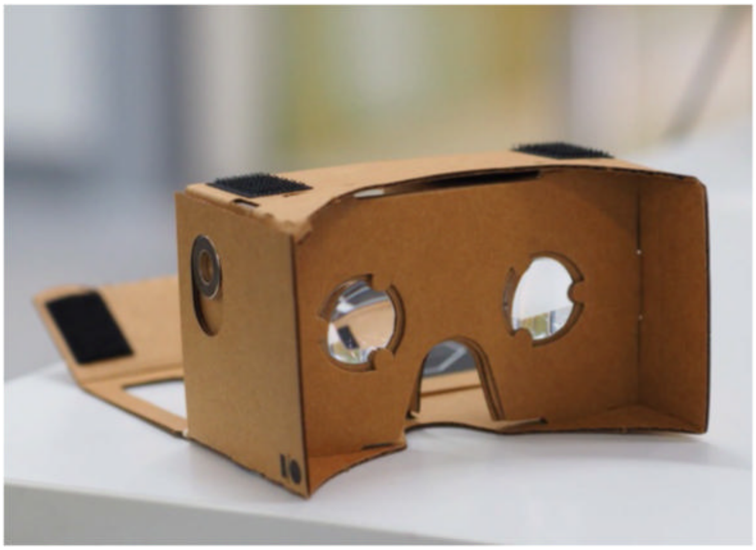
Turn your smartphone into a virtual reality headset with a cardboard box, a magnet and some Velcro!

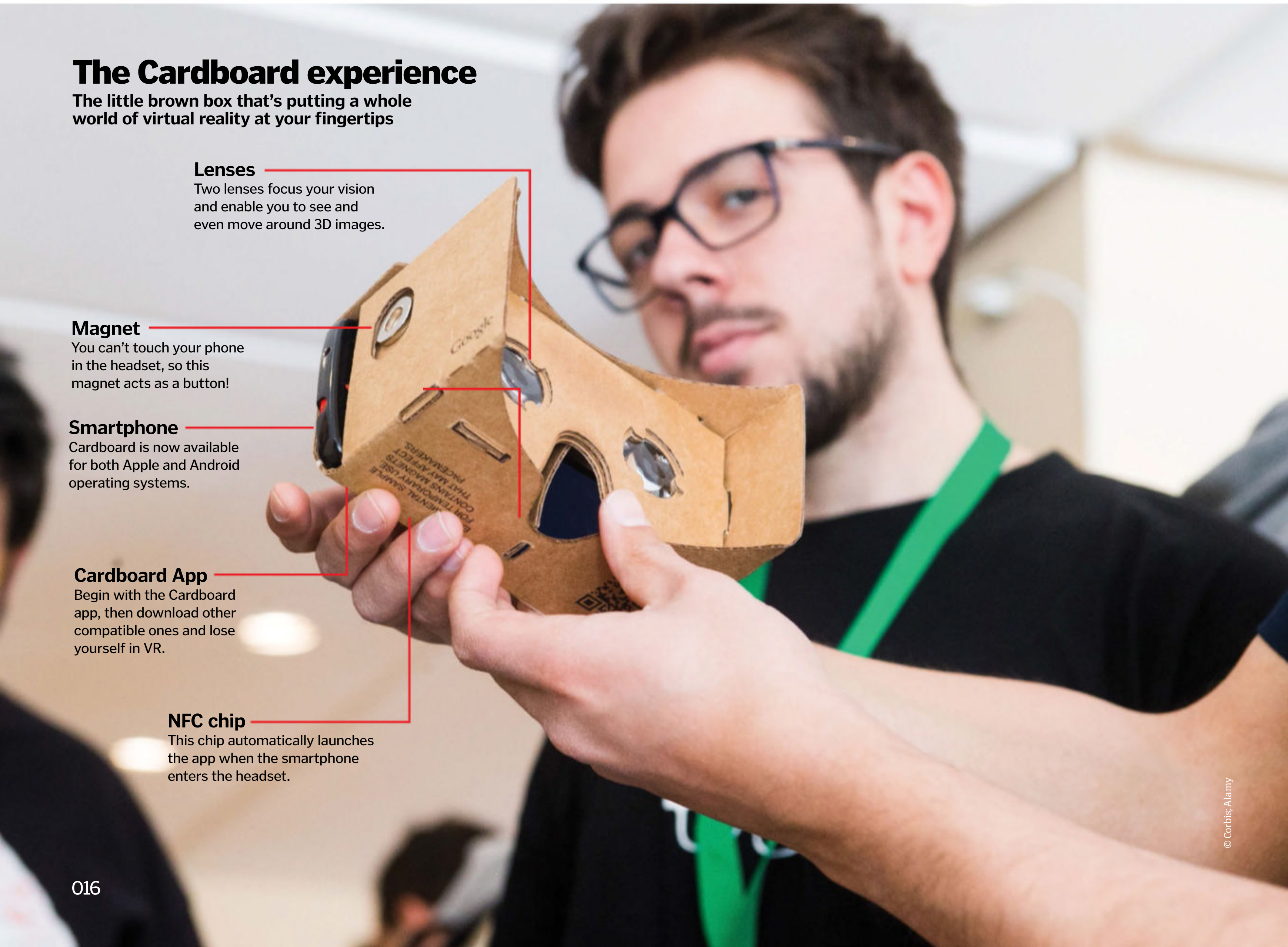
Google's Cardboard venture has opened up the world of virtual reality to everyone. To whisk us away into a fantasy world, Google invites us to make our own VR headset using just a few items that can be found in your garage.

Various cardboard headsets can also be purchased ready-made, so it's not all about DIY. Once you've sourced the headgear, all you need to do is download the Google Cardboard app to get started.

Your smartphone sits in the headset and the app shows you a specially designed split-screen view. When you look at the screen through the headset's lenses that are placed at an optimum distance from the screen, this concentrates your field of view and creates a 3D effect. Your smartphone's motion sensor detects your movement and so all of these factors come together to enable you to walk, run and jump through your very own virtual world.

Google has made this technology incredibly accessible for developers, so there is also a huge array of compatible VR apps available to take your Cardboard experience to the next level.





The Cardboard experience

The little brown box that's putting a whole world of virtual reality at your fingertips

Lenses
Two lenses focus your vision and enable you to see and even move around 3D images.

Magnet
You can't touch your phone in the headset, so this magnet acts as a button!

Smartphone
Cardboard is now available for both Apple and Android operating systems.

Cardboard App
Begin with the Cardboard app, then download other compatible ones and lose yourself in VR.

NFC chip
This chip automatically launches the app when the smartphone enters the headset.

© Corbis; Alamy

How a smartphone knows up from down

The secret lies in a tiny device called an accelerometer

Have you ever wondered how your phone's compass knows which way you're headed? It's all down to the accelerometer, which is built into the circuitry of all modern-day smartphones. It can detect changes in orientation and tell the phone to respond accordingly by rotating its screen.

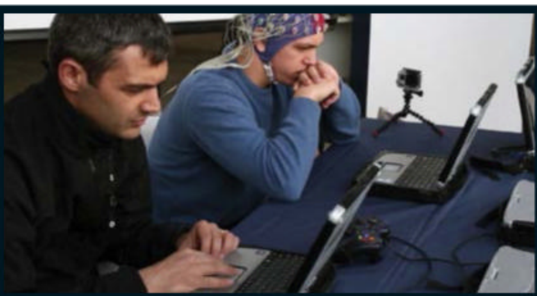
Accelerometers are made up of two fundamental parts. The first is the housing, which attaches to the object in question. The second is some form of mass, which is capable of moving when the object's orientation changes. This movement is the key to how it works, and is what the device measures in order to identify a change in the phone's orientation.

The accelerometer fitted inside a smartphone is an incredible piece of engineering. It is only 500 microns across, and is made by etching into a piece of silicon using potassium hydroxide. This clever device can be used for more than just identifying the orientation. It can be employed in gaming, particularly in driving games, where the user steers a vehicle by tilting their smartphone. They can also be used like a pedometer to track your daily steps, or even to detect tremors as part of an earthquake early warning system.

Apple has included an accelerometer in each generation of iPhone, iPad and iPod Touch

REAL-LIFE SUPERPOWERS

REVEALED: THE TECH THAT CAN MAKE YOU STICK TO WALLS AND REGENERATE LIMBS



We've all dreamed of being one of the superheroes we read about in comic books or watch in big screen blockbusters, but the abilities that make these characters so extraordinary have always been completely fictional – until now.

Amazing advances in technology are enabling humans to develop exciting new ways to mimic the inhabitants of the superhero realm. From gloves that help you climb like Spider-Man, to contact lenses that give you Superman's telescopic vision, the superhero dream is fast becoming reality.

However, these real-life developments aren't being made by billionaires hoping to fight crime and take down dastardly villains; they are actually the ideas of scientists and doctors looking to enhance the human body for more everyday benefits. For example, an implant that speeds up the re-growth of human tissue could be used to reduce the risk of infections and cut medical costs, rather than conceal Wolverine's retractable claws. And a suit that can sense obstacles in any direction could help the visually impaired safely find their way around, instead of providing costume-clad heroes with the means to predict an oncoming attack.

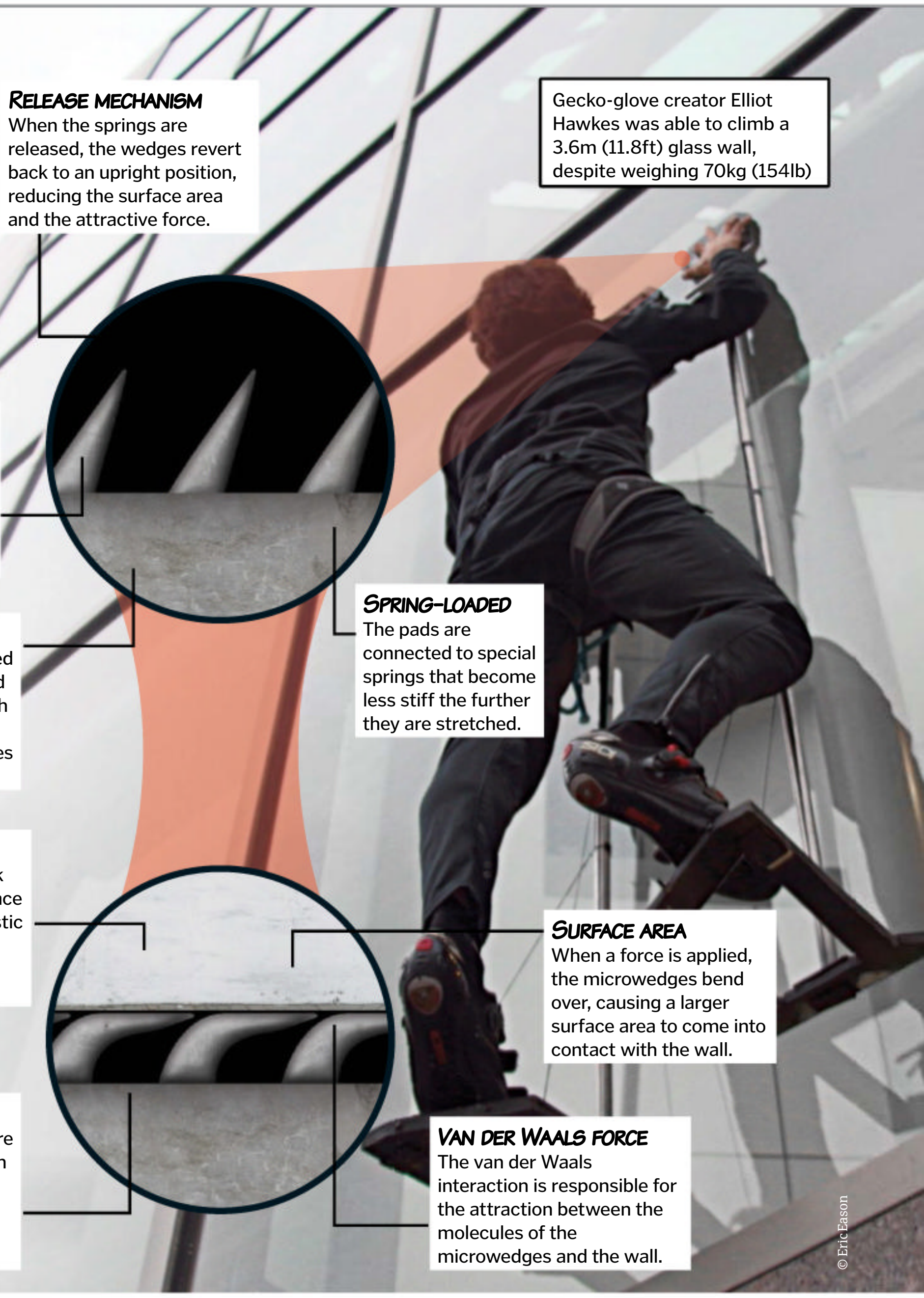
While some of these genius ideas are still in the development phase, others are a lot closer to reality than you might think. Defence contractor Raytheon has already created an amazing Iron Man suit designed to give the US Army's soldiers super-strength, and ship builders are currently using a similar robot exoskeleton to help them lift heavy machinery. You can even get started creating your own superhero gadget at home, as students at the University of Rochester, New York, have found a way to create an invisibility device from readily available materials.

It may not be time to don your mask and cape just yet, but over the next few pages you can browse the incredible gadgets and gizmos that could be kitting out your very own Batcave in the not-so-distant future.

CLIMB UP WALLS LIKE SPIDER-MAN

THE STICKY GLOVES INSPIRED BY A GECKO'S FEET

Being able to scale skyscrapers like everyone's favourite web-slinging superhero would certainly make your morning commute more fun, but the secret to harnessing this power comes from geckos rather then our eight-legged friends. Students at Stanford University have created special dry adhesive gloves that imitate the microscopic hairs found on a gecko's feet, enabling humans to implement the same scientific sticking principle they do. However, a gecko only weighs a few grams, so they had to come up with a clever solution in order to stick an adult human to the wall. This came in the form of special springs, which help to spread a human's weight evenly across the gloves, providing sufficient adhesion to support up to 91 kilograms (200 pounds). Humans don't have the incredible upper-body strength of geckos, though, so a bit of extra help is required in the form of moveable rope ladders that help transfer some of the load to the feet and aid climbing. Initial tests of the gloves have proven successful, and now the students are working with NASA's Jet Propulsion Lab to see if similar technology can be applied to the robotic arms of spacecraft to catch space debris.



Gecko-glove creator Elliot Hawkes was able to climb a 3.6m (11.8ft) glass wall, despite weighing 70kg (154lb)

Release mechanism
When the springs are released, the wedges revert back to an upright position, reducing the surface area and the attractive force.

Microwedges
Each wedge is just 100 micrometers long. That's about the diameter of a couple of strands of human hair.

Adhesive tiles
Each glove is covered with 24 stamp-sized adhesive tiles, which are covered with slanted microwedges made of polymer.

Spring-loaded
The pads are connected to special springs that become less stiff the further they are stretched.

Multi-surface
The gloves can stick to any smooth surface including glass, plastic panels, painted or varnished wood panels and metal.

Surface area
When a force is applied, the microwedges bend over, causing a larger surface area to come into contact with the wall.

Even spread
When the springs are pulled, they apply an identical amount of force to each pad, helping to evenly spread the weight.

Van der Waals force
The van der Waals interaction is responsible for the attraction between the molecules of the microwedges and the wall.

© Eric Eason

GET YOUR SPIDERSENSE TINGLING

Sensors spread across your body can alert you to an oncoming obstacle in a matter of milliseconds

The ability to predict an oncoming obstacle or villain is important for any superhero, but we mere mortals have just created a suit that can help us do the same. It may not look quite as slick as Spider-Man's skin-tight ensemble, but the SpiderSense suit can alert you to any person or object within a 152-centimetre (60-inch) radius, even if you're blindfolded. It contains several sensor modules, each containing a range finder and a servo motor. The range finder continually emits a sonar pulse that bounces off of any nearby obstacles, enabling a sensor to calculate its distance from you. When an obstacle is detected, the servo motor – the same one found in most remote-controlled aeroplanes – activates an arm that applies pressure on your skin. The closer you get to the obstacle, the more pressure the arm applies, allowing you to judge its proximity and act accordingly. Inventor Victor Mateevitsi hopes the tech can help the visually impaired and those in low-visibility situations, such as firefighters entering smoke-filled buildings, to navigate safely.

© Lance Long, Electronic Visualization Laboratory, University of Illinois at Chicago

SUPER-SUITS

FORGET CAPES AND LYCRA OUTFITS, REAL-LIFE SUPERHEROES USE ROBOT EXOSKELETONS

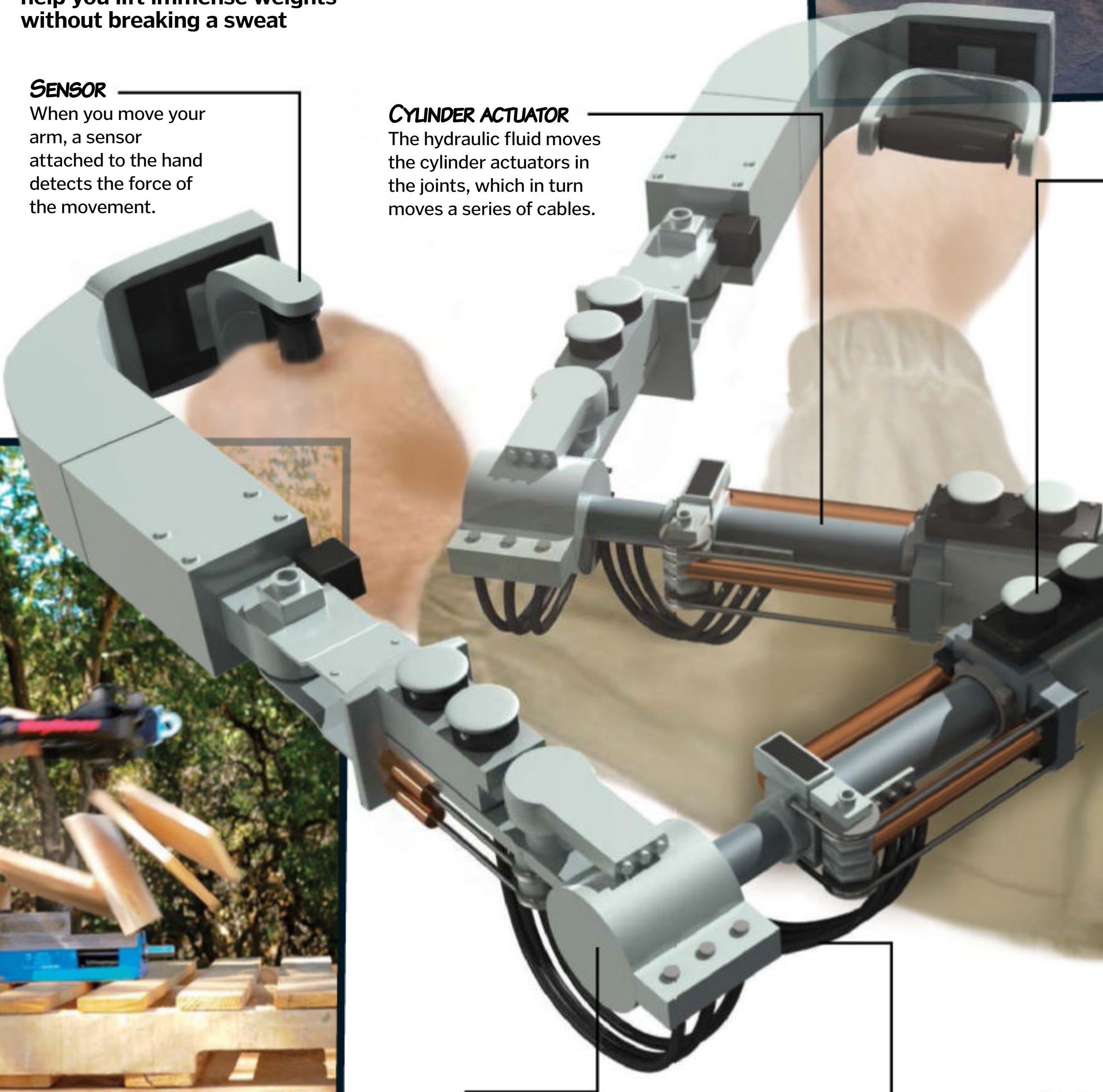
Iron Man's superpowers don't stem from a radioactive spider bite or exposure to gamma rays; they are simply the result of some very clever engineering – and quite a bit of money too. It makes sense then that we should try to replicate his powerful suit, and some companies are already coming incredibly close.

Raytheon, a US defence contractor, has developed a super-strong robotic exoskeleton for the US Army. Soldiers can simply strap into the suit and its high-pressure hydraulic system will enhance their strength, agility and endurance, enabling them to be extremely physically active without risk of exhaustion or injury. The current version must be tethered to its power source, an internal combustion hydraulics engine, but an untethered version is expected to be operational by 2020.

It's not just the military that can benefit from exoskeletons, though, as Lockheed Martin has also designed a suit specifically to help workers operate heavy machinery. The FORTIS helps to carry the weight of tools, enabling the operator to work for longer between breaks required to recover from muscle fatigue.

RAYTHEON XOS 2

The incredible exoskeleton that can help you lift immense weights without breaking a sweat



SENSOR
When you move your arm, a sensor attached to the hand detects the force of the movement.

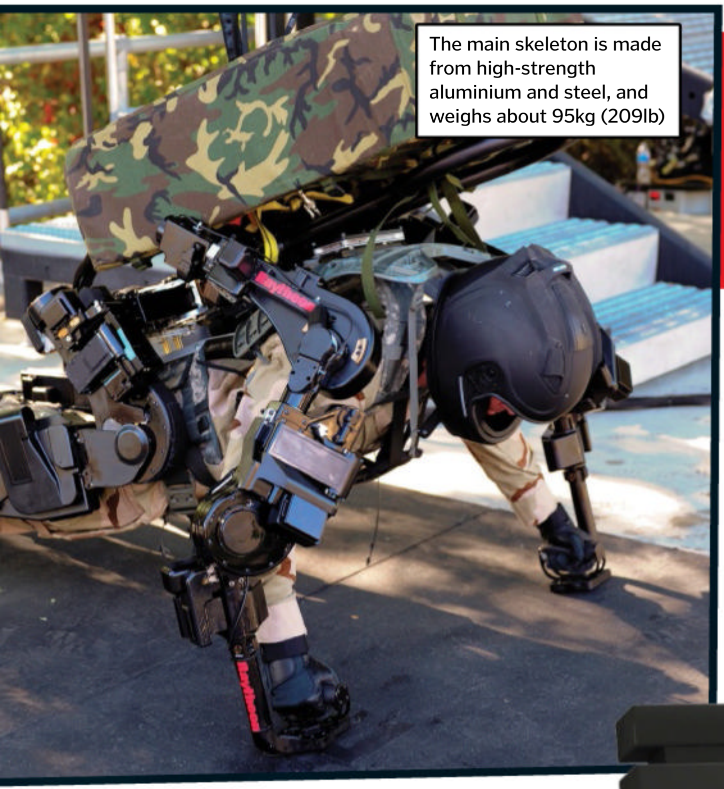
CYLINDER ACTUATOR
The hydraulic fluid moves the cylinder actuators in the joints, which in turn moves a series of cables.

JOINTS
The XOS 2 has 30 cylinder actuators and computers controlling each of the different joints in the exoskeleton.

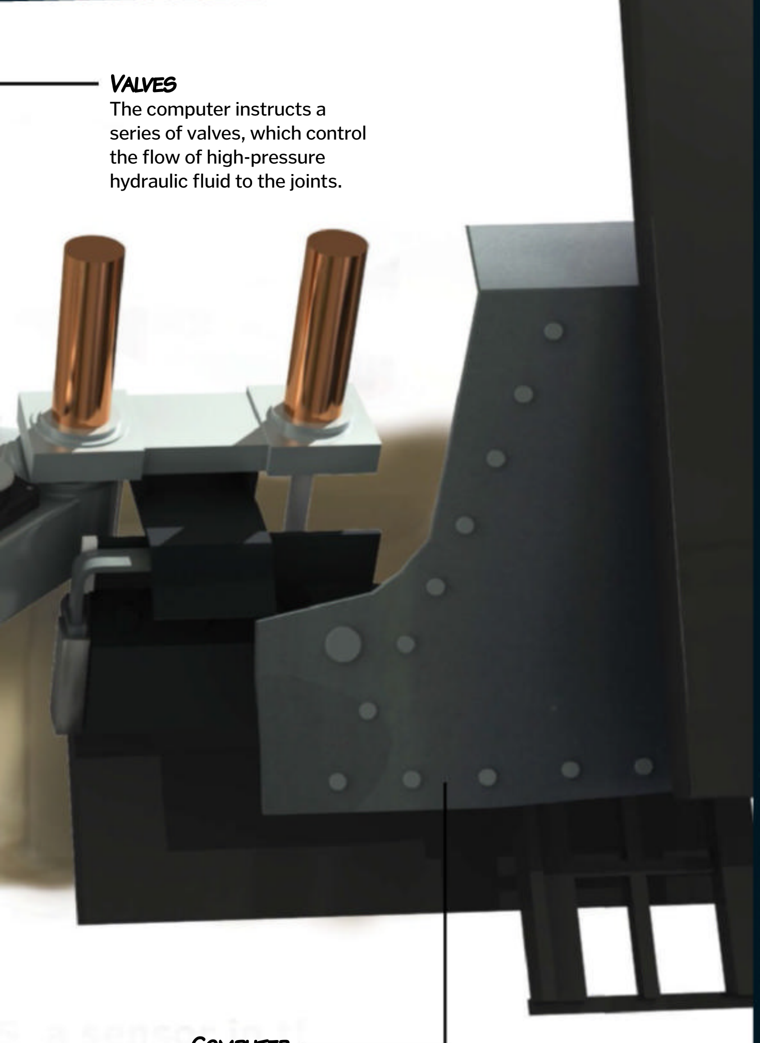
CABLES
The cables act as muscle tendons, pulling on the exoskeleton's limb to move it in the desired direction.

The wearer can punch through 7.6cm (3in) of wood with minimal effort

DID YOU KNOW? *We've been building autonomous machines, or robots, since Ancient China, Ancient Greece, and Ptolemaic Egypt*



The main skeleton is made from high-strength aluminium and steel, and weighs about 95kg (209lb)

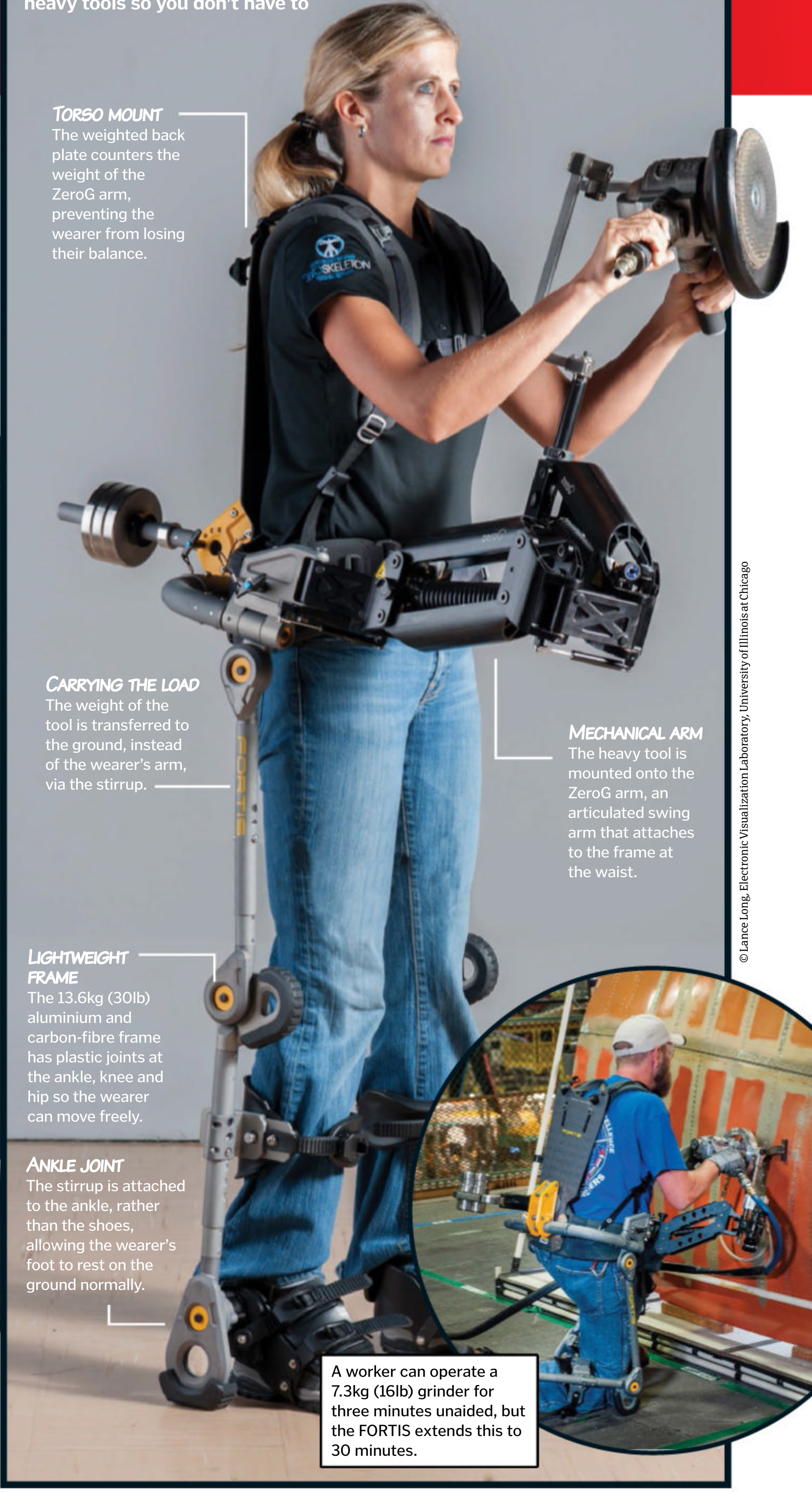


VALVES
The computer instructs a series of valves, which control the flow of high-pressure hydraulic fluid to the joints.

COMPUTER
The computer uses the sensor's data to calculate how to move the exoskeleton to mimic the arm's movements and minimise its strain.

Lockheed Martin FORTIS

The suit that supports up to 16kg (36lb) of heavy tools so you don't have to



TORSO MOUNT
The weighted back plate counters the weight of the ZeroG arm, preventing the wearer from losing their balance.

CARRYING THE LOAD
The weight of the tool is transferred to the ground, instead of the wearer's arm, via the stirrup.

MECHANICAL ARM
The heavy tool is mounted onto the ZeroG arm, an articulated swing arm that attaches to the frame at the waist.

LIGHTWEIGHT FRAME
The 13.6kg (30lb) aluminium and carbon-fibre frame has plastic joints at the ankle, knee and hip so the wearer can move freely.

ANKLE JOINT
The stirrup is attached to the ankle, rather than the shoes, allowing the wearer's foot to rest on the ground normally.

A worker can operate a 7.3kg (16lb) grinder for three minutes unaided, but the FORTIS extends this to 30 minutes.

© Lance Long, Electronic Visualization Laboratory, University of Illinois at Chicago

A simple set-up of four lenses can make an object appear invisible

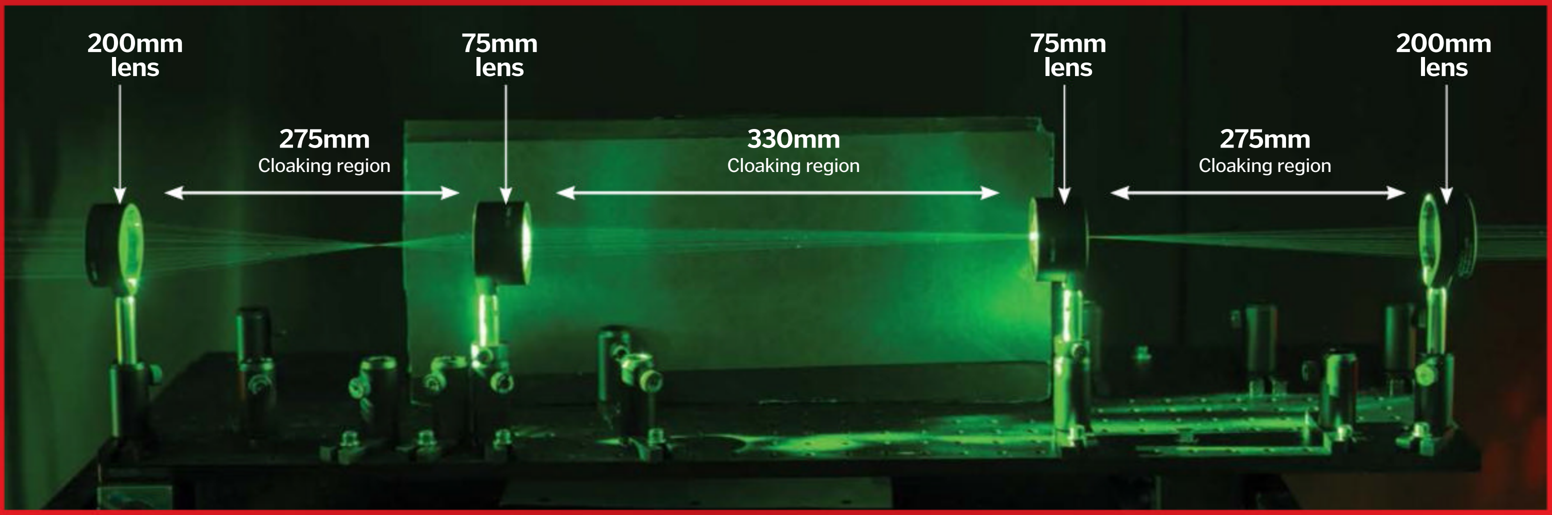
BUILD YOUR OWN INVISIBILITY CLOAK

USE A SIMPLE SET OF LENSES TO SEE THROUGH OPAQUE OBJECTS

Invisibility and the power to see through objects are two of the most sought-after superpowers, but did you know that not only are they already possible, but you can also demonstrate them yourself at home? Students at the University of Rochester have developed a cloaking device using inexpensive, readily available materials that pass light around an object to make it look as though it isn't there. This optical illusion requires four lenses of varying focal lengths, positioned at specific distances from each other. As light rays enter the first lens, they focus and then diverge outward to bend around an object positioned within the cloaking region. This process inverts the image of the background behind the object, so another set of lenses is needed to turn the image up the right way again. The device also allows for multidirectional cloaking, meaning you can look through the first lens from any angle and still see an accurate view of the background behind your invisible object.

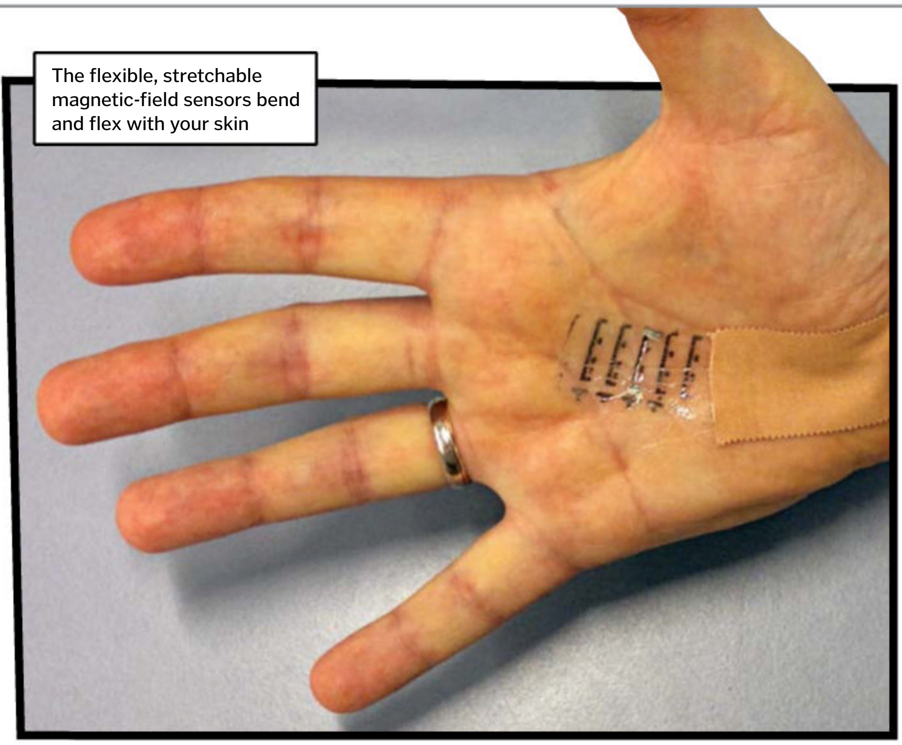
This simplified set up will only cloak objects within a doughnut-shaped region around the edge of the lens, but a more complex and advanced version has been built, which will solve this problem.

The team behind the Rochester Cloak device hope that it could be put to good use by surgeons, allowing them to look through their hands to see exactly what they are operating on, and by truck drivers, allowing them to see through blind spots on their vehicles.



© J. Adam Fenster/University of Rochester

DID YOU KNOW? *The magnetic poles do not align with Earth's poles, and sometimes, a compas will not point to the "true North"*



The flexible, stretchable magnetic-field sensors bend and flex with your skin

MAGNETIC SIXTH SENSE

THE ARTIFICIAL SKIN THAT HELPS YOU NAVIGATE USING EARTH'S MAGNETIC FIELD

Birds and sharks don't need GPS to help them navigate the skies and oceans, but even some superheroes are still reliant on this technology to help them find their way around cities and evil lairs. We could soon be able to do away with sat navs and Google Maps completely, though, as scientists have developed an electronic skin that enables humans to sense magnetic fields and use them to navigate.

The artificial skin contains thin metallic films of cobalt and copper, which reveal changes of the electrical resistance when exposed to a magnetic field. By measuring this resistance change, your proximity to a magnetic field source can be calculated and transmitted to an LED display, giving you a visual representation of your distance from it.

This magnetic field sensor is prepared on a flexible foil called polyethylene terephthalate (PET), similar to the material used to make transparent sheets for overhead projectors, and then applied to an elastic support to make it stretchable. One square meter (10.8 square feet) of the skin is less than two micrometers thick, less than one-tenth the thickness of a human hair, and weighs just three grams (0.1 ounces). This means it can be fixed on or even under your own skin, without you being able to feel its presence.

STRETCHABLE BREAKTHROUGHS

DR DENYS MAKAROV EXPLAINS THE FUTURE POSSIBILITIES OF HIS INCREDIBLE INVENTION

Did sensors like these already exist before your invention?
There were other groups trying to develop magnetic field sensors that are bendable, but we went much further and developed stretchable magnetic-field sensors you can use for on-skin applications. So at the moment, we are the only group in the world that has this technology.

What are the other potential uses for this technology?
The sensors can also be used for biomedical applications, especially for functional medical implants. In conjunction with a magnetic-field source, they can be applied to monitor, in real-time, the displacement of joints or artificial joints, as well as the expansion and contraction of muscles. For example, the real-time activity of the heart muscle can be monitored to detect potential cardiovascular irregularities. The advantage would be to recognise potential health risks at early stages. When combined with wireless communication modules, the sensors can provide immediate alerts to a mobile device or even warn doctors upon detecting muscle dysfunctions.

Another application, surprisingly, is for electrical machines. If you want to make electric motors more efficient, for example to increase the range of an electric car between charges, then you need to optimise the design of the electric motor. This can be done based on the information obtained from magnetic-field sensors, which are measuring the magnetic fields between the rotor and stator of the motor. There is strong interest from car manufacturers in ultra-thin and flexible sensor solutions, because the standard magnetic-field sensors available on the market are simply too thick and rigid and don't fit into the gap between the rotor and stator.

When do you expect the sensors to become available for general use?
We are already providing flexible magnetic-field sensors to industry partners for field testing, but stretchable sensors are not yet commercialised. For medical applications there are many issues to solve. You have to prove they are biocompatible, that they are not going to disturb the function of the organs and so on. So I would say that is a little further away. Maybe within the next five to ten years, we will have on-skin electronic devices that are stretchable and don't contain any rigid components.

© IFW Dresden

SPEEDY SELF-HEALING

THE SMART IMPLANT THAT CAN REGROW SKIN AND BONE JUST LIKE WOLVERINE

In addition to his reinforced metal skeleton complete with retractable claws, Wolverine also has the ability to self-heal at an incredibly fast rate. The human body is actually quite good at healing damaged tissue, but has never been able to match the instantaneous regeneration of this member of the X-Men crew – until now, that is.

A medical implant infused with tissue regeneration molecules called growth factors has now been developed to speed up the body's natural healing process. It may not be quite as quick as Wolverine's superpower just yet, but it could significantly shorten recovery times for patients with damaged skin and bone tissue.

As well as having incredible healing powers, FeyeCon's Intelliplant also has a number of other clever benefits. First, it's made from biodegradable materials, so once the damaged tissue has healed, it gradually dissolves into natural substances already present in the human body. It can also be infused with antibiotics, to minimise the risk of infection when the body tries to attack this foreign object within it.

Scientists working on the project are still fine-tuning the Intelliplant for use with different types of human tissue, but this revolutionary product is expected to be available in hospitals very soon.

The Intelliplant targets specific cells in your body and stimulates them to regenerate quicker

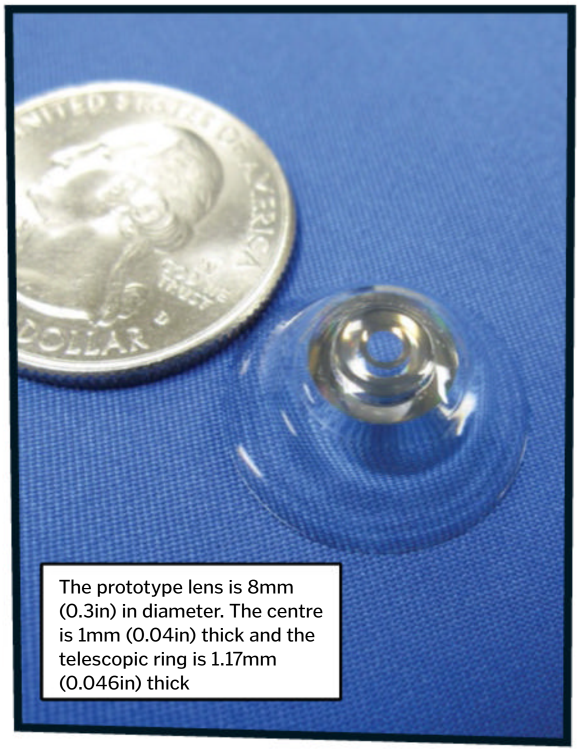
TELESCOPIC EYESIGHT

CONTACT LENSES THAT LET YOU ZOOM IN WITH A WINK

Superman has telescopic vision to help him spot trouble from miles away, but humans are replicating this power for an entirely different purpose. Age-related macular degeneration (AMD) is the leading cause of blindness in older people all over the world, and results from damage to a part of the eye called the macula, which handles fine detail.

To help strengthen the vision of AMD sufferers, researchers from San Diego and Switzerland have developed a telescopic contact lens that can magnify your vision by 2.8 times. The rigid contact lens is larger than an ordinary lens, but still a big improvement on the current treatment for AMD, which involves having to wear bulky glasses with telescopic lenses. Special glasses do still need to be worn with the contact lenses, but these are adapted from a pair of Samsung 3D glasses that have been fitted with a particularly useful high-tech feature.

Sensors on the frames allow you to switch between normal and telescopic vision with a wink. Winking your right eye activates 2.8 times magnification, while winking your left eye turns it off. Eric Tremblay who led the research team at the Swiss Federal Institute of Technology says: "At this point this is still research, but we are hopeful it will eventually become a real option for people with AMD."

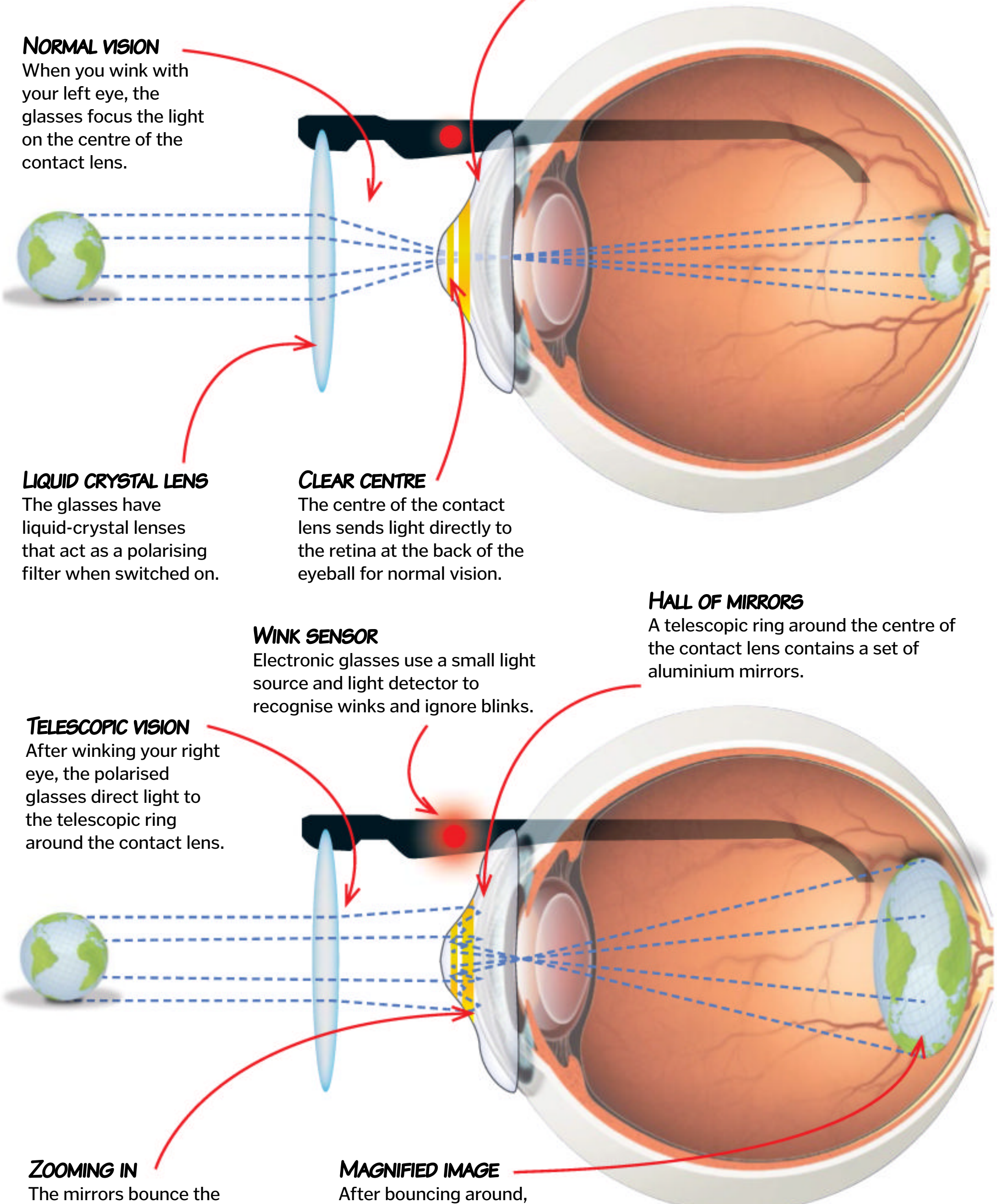


The prototype lens is 8mm (0.3in) in diameter. The centre is 1mm (0.04in) thick and the telescopic ring is 1.17mm (0.046in) thick

You will be able to zoom in on things in your field of vision with a simple wink

Wink to zoom

How contact lenses and glasses work together to magnify your sight



BREATHABLE LENSES
Tiny air channels roughly 0.1mm (0.004in) wide allow oxygen to flow around and underneath the lens and get to the cornea.

NORMAL VISION
When you wink with your left eye, the glasses focus the light on the centre of the contact lens.

LIQUID CRYSTAL LENS
The glasses have liquid-crystal lenses that act as a polarising filter when switched on.

CLEAR CENTRE
The centre of the contact lens sends light directly to the retina at the back of the eyeball for normal vision.

HALL OF MIRRORS
A telescopic ring around the centre of the contact lens contains a set of aluminium mirrors.

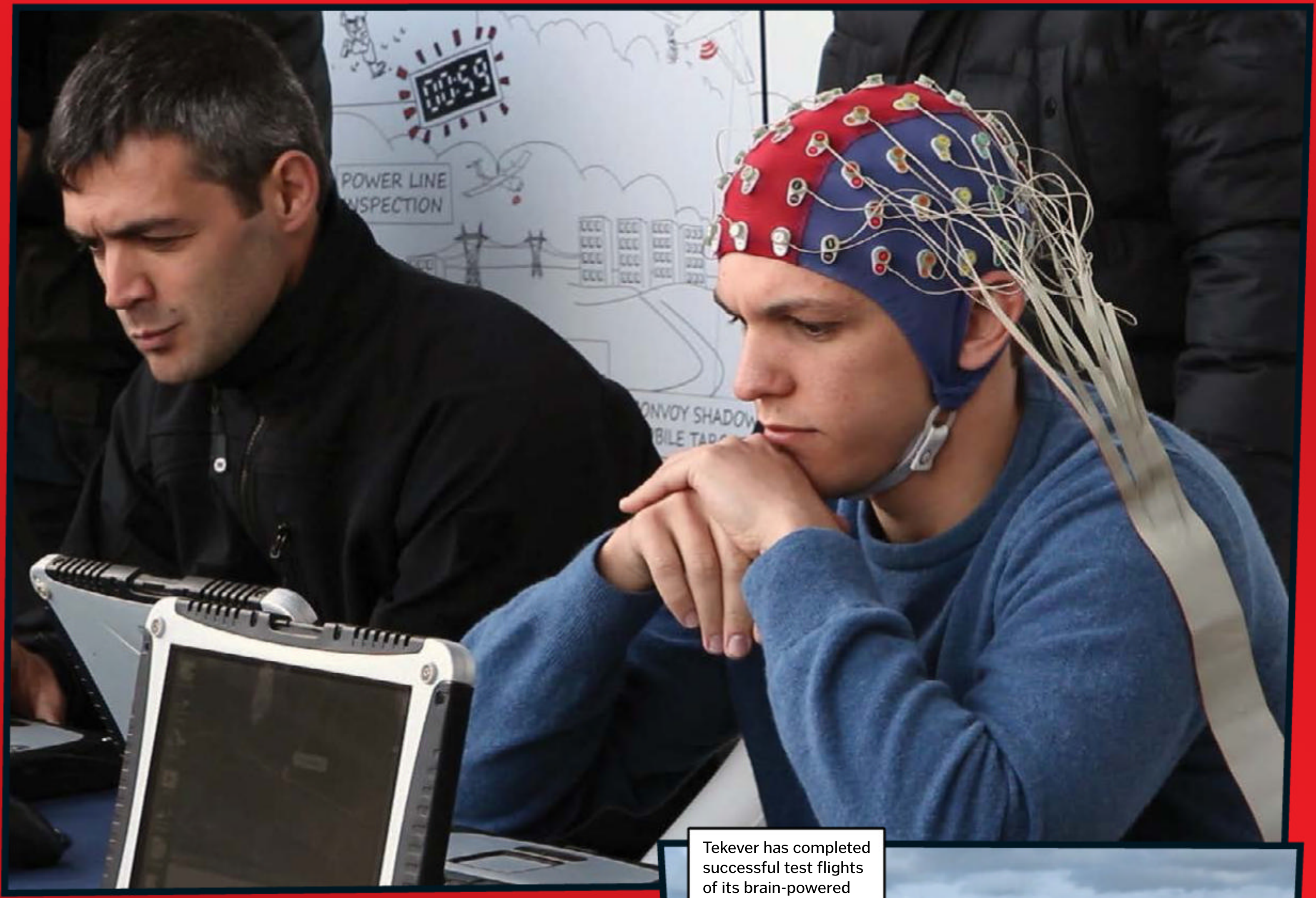
WINK SENSOR
Electronic glasses use a small light source and light detector to recognise winks and ignore blinks.

TELESCOPIC VISION
After winking your right eye, the polarised glasses direct light to the telescopic ring around the contact lens.

ZOOMING IN
The mirrors bounce the light around the ring four times, magnifying the image by 2.8 times.

MAGNIFIED IMAGE
After bouncing around, the light is then directed to the retina at the back of the eyeball.

DID YOU KNOW? *Thanks to a neural implant, people have been able to operate robotic limbs with their mind in recent tests*



MIND CONTROL

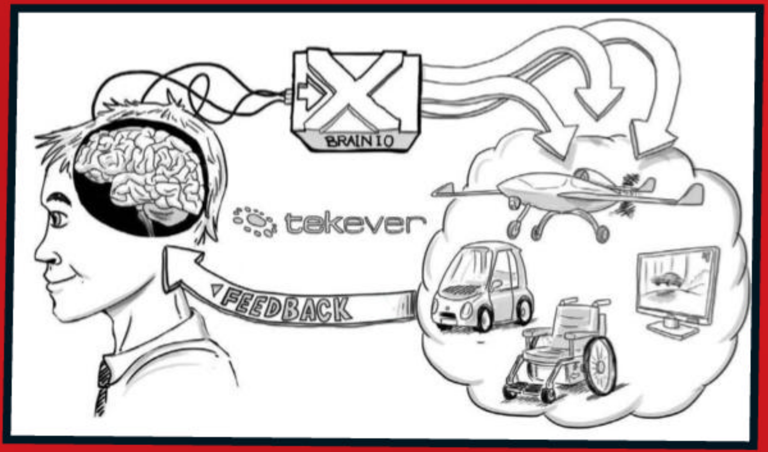
MANIPULATING THE WORLD WITH THOUGHT ALONE

Being able to move and control physical objects with your mind would certainly save you quite a bit of effort in your day-to-day life, but unfortunately telekinesis is only the work of science fiction. However, with a bit of intervention from technology, brainpower can be harnessed to perform all sorts of useful functions.

This real-life superpower is made possible by attaching electroencephalography (EEG) sensors to the scalp, which can measure brain activity. When you concentrate on an object, your brain's prefrontal lobe, located just behind your forehead, fires neurons which create electromagnetic waves. These waves are strong enough to induce a voltage in EEG sensors, which can be interpreted by a computer algorithm and translated into electronic commands for a connected device.

The aerospace tech firm Tekever is currently using this technology to fly drones using just the power of thought. Pilots wearing EEG skullcaps train their brain to think about moving a small circle on a computer screen up to turn the drone left or down to turn it right. The sensors then detect the activity occurring in specific parts of the brain to issue instructions to the software that controls the drone. The company hopes that one day this technology could be used to control much larger aircraft to help reduce the workload of pilots and also to enable physically disabled people to fly an aircraft.

Tekever has completed successful test flights of its brain-powered drone in Portugal



© Tekeva; Thinkstock;

Smartwatches

Discover how the latest must-have gadget has been developed over the last 75 years

The smartwatch might seem like a brand new invention, but it has actually been around in some form or another for decades. The inspiration for a wrist-based device that could do more than just tell the time is often credited to famous fictional detective Dick Tracy. A two-way wrist radio first featured in the comic strip in 1946, but by this time the first real-life multi-functional wearable device had already appeared on the scene – and inspired generations yet to come.

Early smartwatches were typically timepieces that doubled as calculators, but as technology developed, more features were added to provide for data storage and wireless connectivity to a phone or PC. Modern smartwatches, such as Samsung's Galaxy Gear and the Apple Watch, can now host apps, monitor your heart rate and even pay for your shopping.

Over 373 million smartwatches are expected to have been shipped all over the world by 2020, but we can only speculate about the sort of features these high-tech timepieces will have as we enter the next decade. For now, we can have a look at what current models are capable of.

27 million smartwatches are expected to be shipped in 2015

Measuring your heart rate

60 BPM
72BPM, 23m ago

Talk about wearing your heart on your sleeve; the Apple Watch can measure your heart rate continuously during a workout. It then uses this information to estimate how many calories you have burned and stores all this information in the Health app. The watch uses green LED lights paired with light-sensitive photodiodes to sense the amount of blood flowing through your wrist. It works because blood reflects red light and absorbs green, so when your heart beats, the green light absorption is greater than in between beats. The LED lights are flashed hundreds of times per second, so the watch can work out exactly how many times your heart beats each minute.

SMART WATCH TIMELINE

Explore the evolution of the technology that you thought was brand new

1941

Calculate

The first watch to do something other than tell the time was the Mimo Loga. This slide-rule watch had moveable logarithmic tables that enabled the wearer to make basic calculations when on the go.

1972

LED display

The Hamilton Watch Company made the first electronic digital watch, the Pulsar, with an LED display and 18-carat gold body. In 1975, they also released the first electronic calculator watch.

1980s

Storage

The first watches that could store information included the Seiko D409 with 112-bytes of memory and Casio's Databank series of watches that featured tiny keyboards.

1995

Synced up

The Timex Data Link was the first watch to be able to wirelessly sync with your computer. Special software on your PC flashed in a particular pattern that the watch could translate into data.

1940s

1970s

1980s

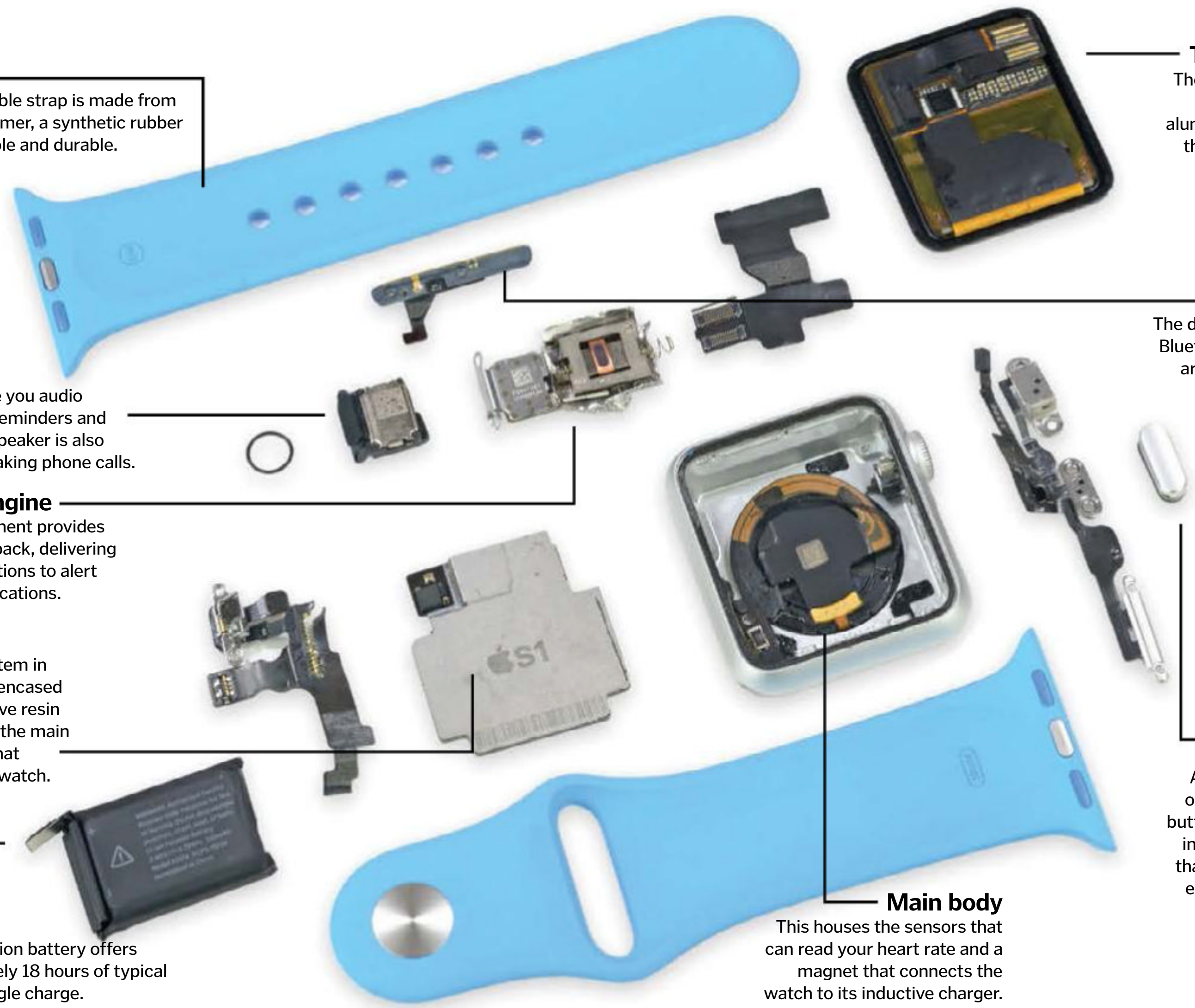
1990s

TIMEX
DATA LINK
16-07-08
PM
8:02.13
WED TZ1
INDIGLO
NEXT
PREVIOUS
SET/DELETE
MODE
Microsoft

DID YOU KNOW? *Gold is not a strong material, so Apple uses a method called Work Hardening to make it more durable*

Inside the Apple Watch

The clever components of the tech giant's Sport device



Strap
The removable strap is made from fluoroelastomer, a synthetic rubber that is flexible and durable.

Touchscreen
The retina display is protected by aluminosilicate glass that is scratch and impact resistant.

Antenna
The device's Wi-Fi and Bluetooth capabilities are handled by this tiny component.

Speaker
Used to give you audio directions, reminders and alerts, the speaker is also crucial for taking phone calls.

Taptic Engine
This component provides haptic feedback, delivering subtle vibrations to alert you to notifications.

S1 SiP
Apple's 'system in package' is encased in a protective resin shell, and is the main processor that powers the watch.

Encoder
A push or twist of one of the watch's buttons is converted into a digital signal that the S1 chip can easily understand.

Battery
The lithium-ion battery offers approximately 18 hours of typical use on a single charge.

Main body
This houses the sensors that can read your heart rate and a magnet that connects the watch to its inductive charger.

2000
Run Linux
The IBM Linux Watch and WatchPad 1.5 were the first devices to run the Linux operating system. The latter also featured a touchscreen, a fingerprint scanner and Bluetooth.

2004
FM signals
Microsoft's Smart Personal Object Technology (SPOT) watches were released. They received FM radio broadcast signals to display news and weather updates.

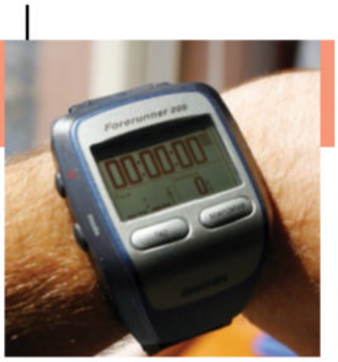
2006
Keep fit
The first sports watch/wearable fitness tracker was Garmin's Forerunner with built-in GPS and the ability to track speed, distance, pace and also calories burned.

2009
Added SIM
Samsung's S9110 watchphone featured a SIM card so could be used to make calls and texts, and play music. It was also the slimmest device of its kind on the market at just 11.98mm (0.47in) thick.

2013
The Pebble
After a successful Kickstarter campaign that raised over £6.5 million ($10 million), the Pebble Watch was released. It has an e-paper display and is compatible with both iOS and Android smartphones too.

2015
Apple Watch
Following the release of various Android smartwatches, such as the Samsung Galaxy Gear, Apple's highly anticipated smartwatch successfully went on sale with 38 different versions.

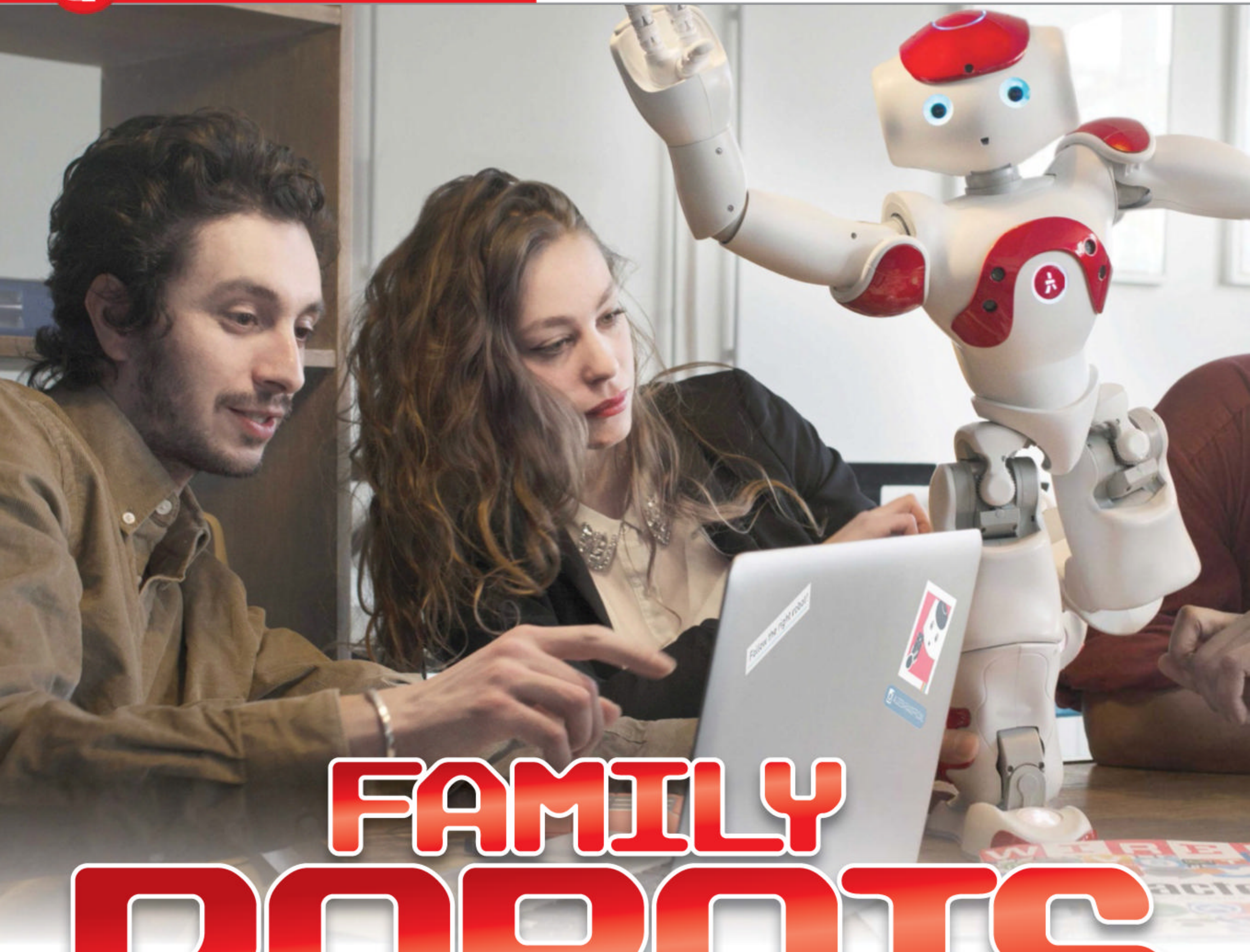
2000s



2010s>

twelve
thirty
five

© Corbis; Apple; Ifixit



FAMILY ROBOTS

Meet the robotic helpers who want to work their way into your home and your heart

R2-D2, C-3PO, Rosie Jetson, Johnny 5, Wall-E – popular culture is packed with examples of friendly, sentient robot sidekicks who just want to serve us. Yet despite the human race having sent robots to Mars and beyond, there remains a distinct lack of interactive robots in most of our daily lives. But that might finally be about to change thanks to a few key developments.

Of course, NASA has more money to throw at robotics than us mere mortals. Today, however, the processors, sensors, tiny motors and other components involved are vastly improved and have become much cheaper to produce, thanks largely to the smartphone revolution. Advances in 3D printing and the open source software movement have dragged costs down even further, to the point where emerging social robots are just about in the realm of what is typically seen as affordable – at least for those who can comfortably purchase high-end personal computers or used cars.

A second, arguably even more important, barrier is gradually being overcome too: humanising the technology. It's a fact that, for every adorable R2-D2 in our collective memories, there's a HAL 9000 or a Terminator hell-bent on driving us to dystopia. Stories like *I, Robot* and *The Matrix* have conditioned us to fear a global cybernetic revolt where robots take over our lives and control our every move.

Technology is being developed to enable robots to recognise and respond sensitively to

DID YOU KNOW? *The word robot derives from the Czech word robota (meaning "forced labour"), coined by Karel Čapek in 1920*

our emotions. They can perform gestures and expressions that mimic ours – like sagging shoulders or a curious head tilt –making it easier for us to form bonds with machines.

Unlike fabled "robot servants", family robots are intended to engage, delight and enrich our lives. They will help keep us organised with reminders about appointments or medication doses. They will provide genuine companionship and help the elderly live independently for longer by being present and ready to call for help if needed.

"The most important thing for us is to fight loneliness," explained Bruno Maisonnier – founder of Aldebaran Robotics, a French company that produces a number of social robots including Pepper and NAO – in an interview with Yahoo Tech. "If you're angry and losing your humanity, NAO can detect that and do something to help you bring it back. It actually helps humans be more human. That's the part nobody expects."

JIBO

The most adorable pile of electronics ever just wants to be part of your family

JIBO – the runaway crowd-funding success story that reached its goal within four hours – is pegged as "the world's first family robot" and will start shipping in late 2015. Standing stationary at a diminutive 28 centimetres (11 inches) tall, he eschews the traditional humanoid form in favour of something altogether more Pixar flavoured and he simply wants to make your home life run that little bit more smoothly.

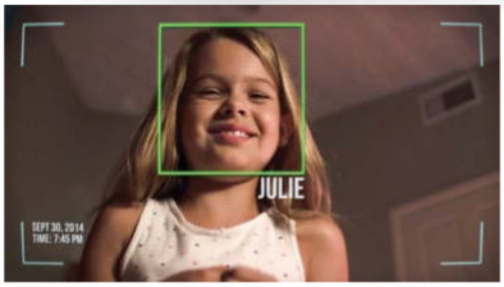
Reading his surroundings with a pair of hi-res cameras and 360-degree microphones, JIBO recognises faces and understands natural language. In-built artificial intelligence algorithms help him learn about you, adapt to your life and communicate with you via a naturalistic range of social and emotive movements, screen displays, gestures and sounds.

JIBO's skillset

The many and varied roles of the "world's first family robot"

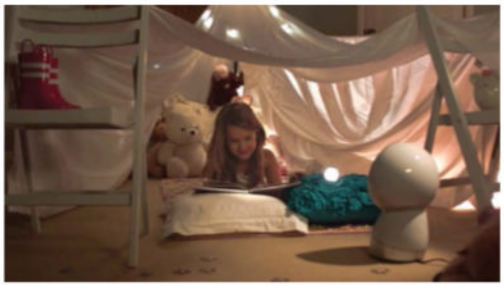
Communication facilitator

JIBO makes video calls with absent friends and family feel like you're actually in the room together. As the incoming caller, you can direct him to look at a specific person with one tap of your finger and his see-and-track camera will follow them naturally as they move around. When a new person chimes in, JIBO will automatically turn to them.



Photographer

Via his dual hi-res cameras, JIBO can recognise faces, identify individuals and track any activity that is going on around him. Using natural cues like movement and smile detection, for example, he can decide the optimal moment to snap a picture, or will obediently oblige your voice command to take the shot.



Storyteller

Story time with JIBO is just as entertaining as it is with a parent. He regales his playmates with tales embellished with sound effects, animated graphics and expressive physical movements and – using his sensors and special interactive apps – reads and responds to the reactions of his enthralled audience.

Personal assistant

JIBO's camera software recognises each member of your household, enabling him to be a hands-free personal assistant to everyone – delivering reminders and messages at the right time to the right person. When you're busy, he'll search the internet for anything you ask for. He'll even log your takeaway order and place it!

© Aldebaran

NAO

Say hello to the friendliest social humanoid, created for companionship

NAO is one of the most sophisticated humanoid robots ever built, not to mention one of the cutest. Standing 58 centimetres (23 inches) tall, he is completely programmable, autonomous and interactive. He can walk, dance, sing, hold a conversation and even drive his own miniature robot car! Currently in his fifth incarnation – known as NAO Evolution – he has, in fact, been constantly evolving since he burst on to the scene in 2006.

NAO reads his surroundings via sensors including cameras, microphones, sonar range finders and tactile pads. Today he can recognise familiar people, interpret emotions and even form bonds with those who treat him kindly – roughly mimicking the emotional skills of a one-year-old child.

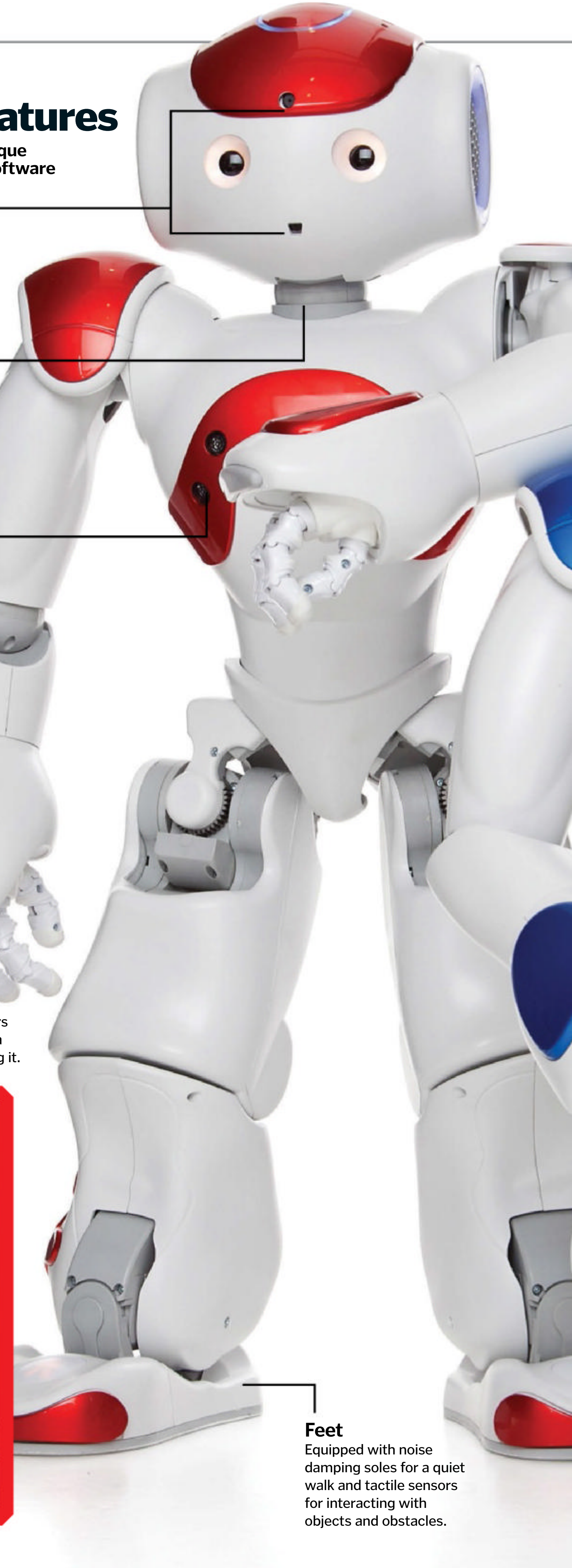
With a battery life of more than 1.5 hours and an electrically motorised body whose joints give him 25 degrees of freedom, he can navigate his world avoiding obstacles, pick himself up if he falls, and – most importantly – bust out impressive dance moves.

A key feature of NAO's programming is the ability to learn and evolve. Over 500 developers worldwide are engaged in creating applications to run on his NAOqi 2.0 operating system and three gigabytes of memory. Being autonomous, NAO can download new behaviours on his own from an online app store.

Today, NAO is the leading humanoid robot used in research and education worldwide, with more than 5,000 NAO units in over 70 countries, according to his creators Aldebaran Robotics.

NAO's best features

He's a little character with a unique combination of hardware and software



Audiovisual input

NAO is equipped with a pair of cameras and can perform facial and object recognition; a suite of four directional microphones enables him to decipher where sounds originate from and recognise voices.

Vocal synthesiser

Includes text-to-speech capabilities for internet recital; able to communicate in 19 different languages.

Sonar system

NAO judges distances to nearby objects and obstacles using a pair of ultrasonic transmitters (top) and a pair of receivers (bottom) that analyse the time it takes for inaudible sound pulses to bounce back.

Prehensile hands

Enable NAO to grasp and manipulate objects. A trio of capacitive touch sensors in each hand let him know when he has a good grip on something without crushing it.

Feet

Equipped with noise damping soles for a quiet walk and tactile sensors for interacting with objects and obstacles.

NAO's sensitive side

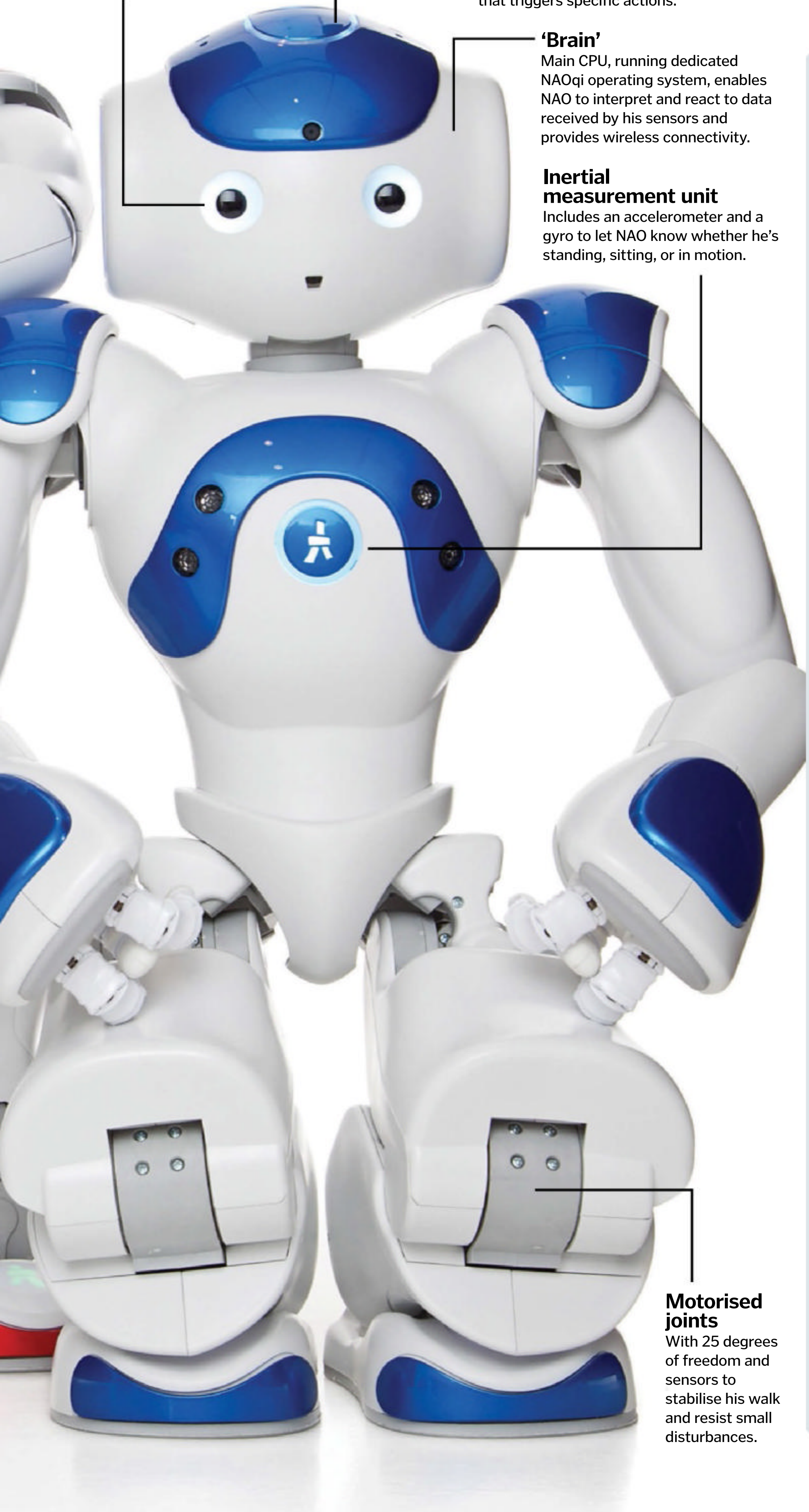
NAO reads human emotions by analysing a set of non-verbal cues. Using data from his cameras, microphones and capacitive touch sensors, he interprets things like how close a person stands, how animated they are, how loud they're being compared to their usual level, what facial expression they're wearing, what gestures they're making and how tactile they are being.

His understanding of emotion has been cultivated using professional actors to help him recognise these non-verbal cues, and he is currently able to accurately detect emotions about 70 per cent of the time. He is programmed with a set of basic rules about what is 'good' or 'bad' for him which help him decide how he ought to respond.

NAO expresses his own emotions via a combination of lifelike postures and gestures (for example, he will cower and shake if he is afraid), vocalisations and sound effects, and coloured lights in his eyes. Using machine-learning algorithms, he picks up new ways to express himself from the people he interacts with – just like a baby.

NAO uses machine-learning to pick up new ways to express himself

DID YOU KNOW? 28% of people surveyed wouldn't pay over $1,000 (£650) for a domestic robot, and 29% wouldn't buy one at all



Infrared transceiver
Permits wireless communication with other NAOs or infrared-enabled devices.

Tactile sensor
Communicate with NAO via touch: press once to shut down, or program the sensor as a button that triggers specific actions.

'Brain'
Main CPU, running dedicated NAOqi operating system, enables NAO to interpret and react to data received by his sensors and provides wireless connectivity.

Inertial measurement unit
Includes an accelerometer and a gyro to let NAO know whether he's standing, sitting, or in motion.

Motorised joints
With 25 degrees of freedom and sensors to stabilise his walk and resist small disturbances.

> "A key feature of NAO's programming is the ability to learn and evolve"

ROBO-HELPERS

Check out how these robot servants could help make household chores a thing of the past!

Floor cleaning

Automatic vacuum cleaners such as iRobot's popular Roomba size up a room and navigate the floor in a random motion as they clean. Roomba's younger sibling, Scooba, can vacuum and wash non-carpeted floors simultaneously, and both devices can be set to clean on a schedule.

Getting up

Good news for people who struggle to get up in the morning: the Clocky robot alarm clock gives users one chance to snooze before it rolls off the bedside table and finds a hiding place – different each day – forcing would-be slumberers to chase it down.

Garden upkeep

Cheating teenagers everywhere out of a little extra pocket money, Robomow works like an outdoor version of the Roomba to keep lawns in pristine condition. It handles all grass types, slopes up to 20 degrees and knows to head for cover as soon as it detects any rain in the air.

Laundry maid

The researchers at UC Berkeley programmed research and innovation robot PR2 to carefully fold fresh laundry back in 2010. Fast-forward four years, and they had it taking dirty laundry to the machine and setting it going too. The catch? Your own PR2 would set you back $400,000 (about £260,000)!

Robo Butlers

A recent PR stunt from the makers of the Wink home automation app touted a revolutionary (and fake!) Robot Butler but, despite a few early inroads like BrewskiBot – a hefty rolling fridge that is designed to shuttle drinks – robotic butlers have yet to be commercially realised.

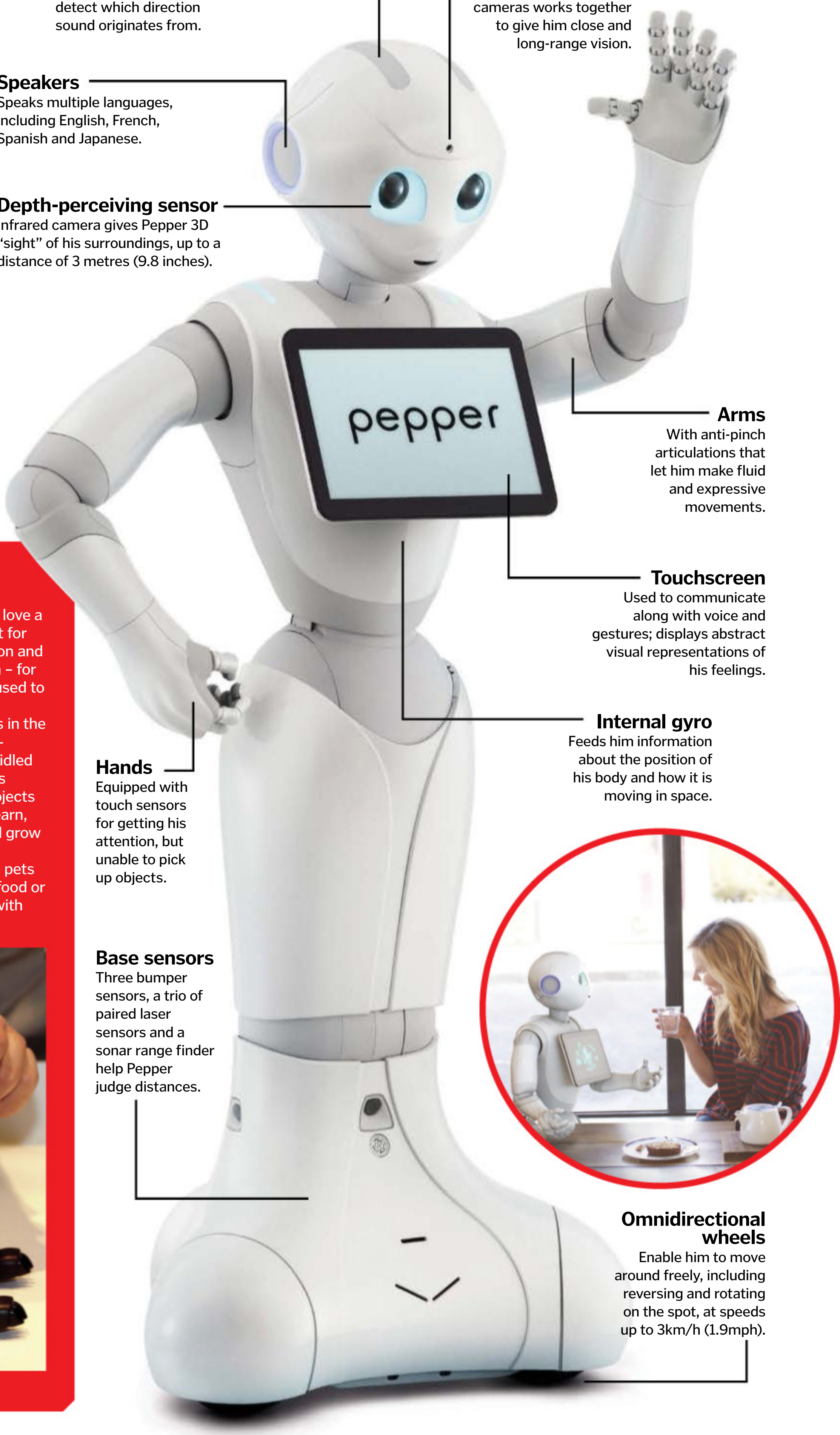
© iRobot; Nandahome; Xinhua / Alamy

PEPPER

The perfect houseguest: a conversationalist who'll adapt to your mood

Pepper is the first autonomous social robot designed to live with humans. Like us, he reads emotions by analysing facial expressions, vocal tone and gestures, and engages people in meaningful mood-appropriate conversations. He exudes 1.2 metres (four feet) "of pure style", rolling around autonomously for up to 14 hours at a time, and even knows when it's time to plug himself in for a recharge.

Pepper learns from his interactions with humans and uploads his generalised findings to the Cloud so that he and other Peppers can evolve as a collective intelligence. This is welcome news because, so far, his jokes are pretty lame! Since June 2014 Peppers have been used in SoftBank Mobile stores in Japan to greet and assist customers. The first 1,000 models were made available to consumers in June this year and sold out in under a minute.



Microphones
Four microphones detect which direction sound originates from.

HD cameras
A pair of HD colour video cameras works together to give him close and long-range vision.

Speakers
Speaks multiple languages, including English, French, Spanish and Japanese.

Depth-perceiving sensor
Infrared camera gives Pepper 3D "sight" of his surroundings, up to a distance of 3 metres (9.8 inches).

Arms
With anti-pinch articulations that let him make fluid and expressive movements.

Touchscreen
Used to communicate along with voice and gestures; displays abstract visual representations of his feelings.

Internal gyro
Feeds him information about the position of his body and how it is moving in space.

Hands
Equipped with touch sensors for getting his attention, but unable to pick up objects.

Base sensors
Three bumper sensors, a trio of paired laser sensors and a sonar range finder help Pepper judge distances.

Omnidirectional wheels
Enable him to move around freely, including reversing and rotating on the spot, at speeds up to 3km/h (1.9mph).

Robotic pets

You may think it's crazy to suggest you could possibly love a robot as much as you love your real-life dog or cat. But for some people, robotic pets offer a chance for connection and companionship that they might otherwise miss out on – for example, older people who are less mobile than they used to be or children with life-threatening allergies.

They've come a long way since the alien-like Furbies in the late 1990s and the multi-functional dogs like Zoomer – which hurls itself around with all the "grace" and unbridled energy of a puppy. Robotic pets have motorised bodies equipped with sensors to detect things like motion, objects and voice commands. Some even have the ability to learn, respond to kindness, develop a unique personality and grow through various life stages, like baby dinosaur PLEO.

Of course, there are the added benefits that robotic pets will never ruin your furniture, don't require expensive food or vet visits and won't demand walks when it's pouring with rain! All the fun – none of the inconvenience!

All the fun – none of the clean up!

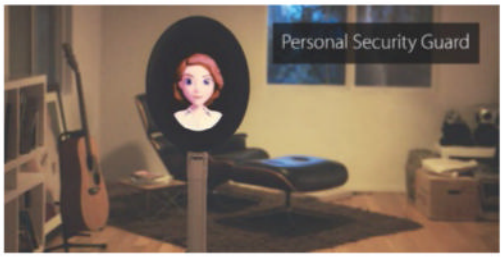
DID YOU KNOW? *During 2002-2012, Roombas collectively covered a distance equivalent to 28 round-trips to the Sun*

PERSONAL ROBOT

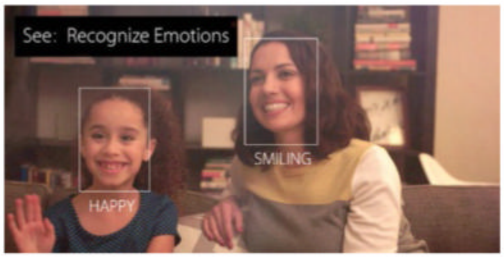
Assistant, security guard, and home automation system all rolled into one

Personal Robot is a smart personal assistant equipped with a heavy dose of artificial intelligence (AI). The 1.2 metre four-foot tall robot consists of a sturdy, wheeled base and a sensor-packed interactive screen carried by a telescopic strut. It navigates its environment autonomously, using in-built mapping algorithms to build and memorise the floor plan.

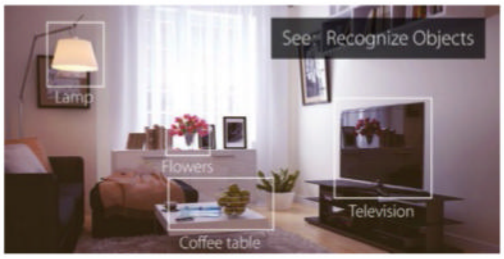
The gender and characteristics of each Personal Robot are customisable and its AI algorithms bring together face, emotion and object recognition, natural language processing and wireless connectivity to allow it to interact seamlessly with its environment and owners. Its creators, New York City start-up RobotBase, expect to start selling the robot by the end of 2015.


Personal Security Guard

Personal security guard
Sends you updates and real-time video feeds so you can check on your home and pets while you're gone.


See: Recognize Emotions
HAPPY
SMILING

Emotionally intelligent
Recognises human emotions by interpreting facial expressions with artificial intelligence (AI).


See: Recognize Objects
Lamp
Flowers
Television
Coffee table

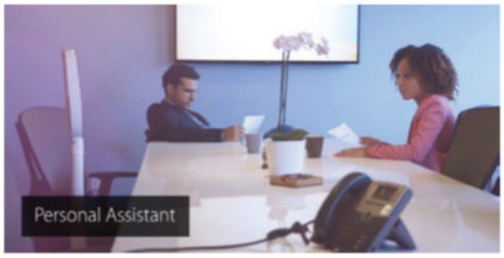
Recognises objects
Identifies familiar household objects and wirelessly connects to and controls compatible appliances.

Feel: Room Temperature, Humidity, Air Quality
Temperature 75 degree
Humidity 38%
CO2 650 ppm (Good)

"Feels" the environment
Uses a suite of sensors to monitor variables like temperature, humidity and air quality.

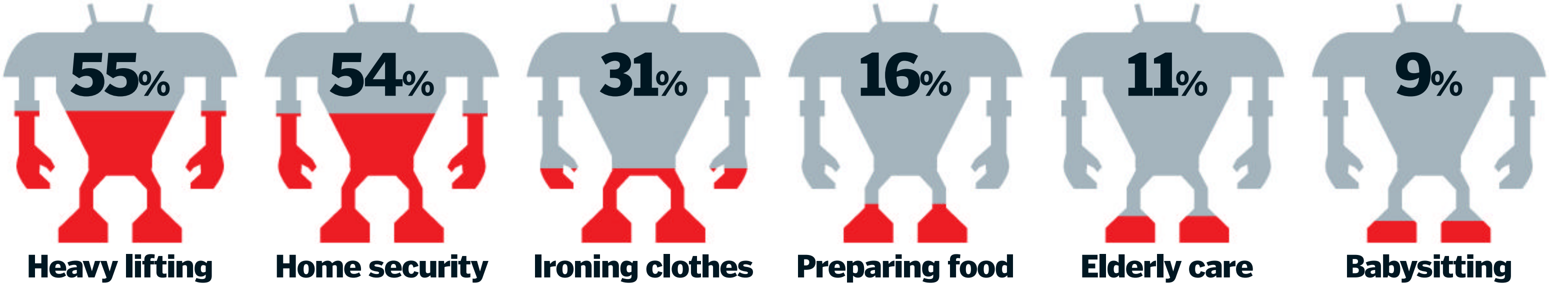
SMILING
HAPPY
SMILING
SMILING
LAUGHING
Personal Photographer

Personal photographer
Recognises good photo opportunities and leaves you free to join your friends in the frame.


Personal Assistant

Personal assistant
Provides wake-up alarms, appointment reminders, fashion advice, fact-checking and business information.

Survey respondents' likelihood of using a robot for various tasks



© Aldebaran; vario images GmbH & Co.KG / Alamy

Wireless chargers

The amazing tech that could spell the end for plugs and cables

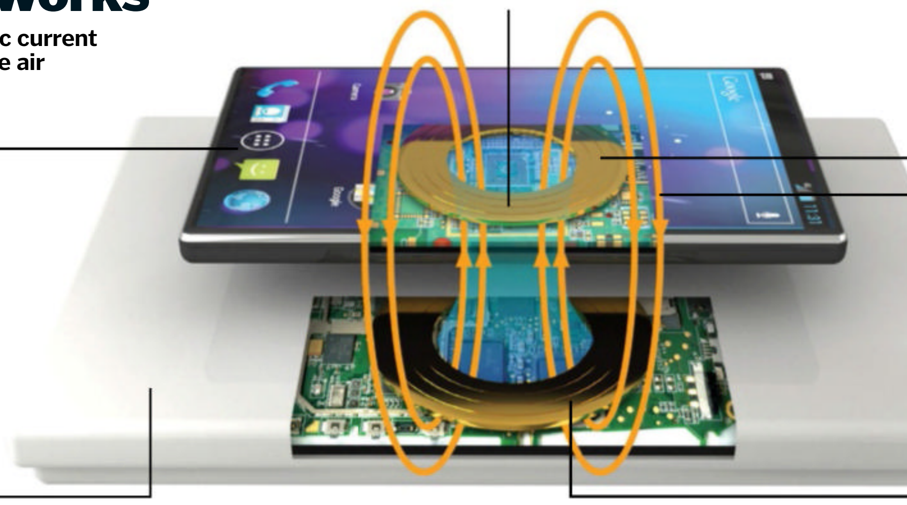
If you have ever had to wrestle with a tangle of cables, the introduction of wireless phone charging will come as a welcome relief – but this useful technology isn't actually all that new. Physicist Nikola Tesla first concluded that you could transfer power between two objects via an electromagnetic field in the late 1800s, and by the 1990s wires and electronics could be made small enough to make wireless charging feasible for devices such as artificial hearts and electric toothbrushes.

These days, the inductive charging method can be used for smartphones, tablets and even electric cars, but if it's so convenient, why aren't we using it all the time? One reason is that it isn't very efficient, as a lot of energy is lost as heat – so your device takes longer to charge. It also requires your device to be very close to the charger to work, so it effectively still tethers it to a power source just like a cable charger.

However, this could change with a new method called inductive wireless charging that is in development and will enable power to be transferred over greater distances.

How inductive wireless charging works

Find out how an electric current can be sent through the air



1 Power source
The power coming from the plug sockets in your walls is alternating current, which changes direction several times a second.

2 Transmitter
The current is sent to the transmitter circuit in the wireless charger, which then sends it to a transmitter coil of wire.

3 Magnetic field
As the alternating current flows through the transmitter coil it creates a changing magnetic field.

4 Receiver
The magnetic field generates an electric current within the receiver coil of a device when it comes within a close distance.

5 Direct current
The alternating current flowing through the receiver coil is then converted into direct current by the receiver circuit.

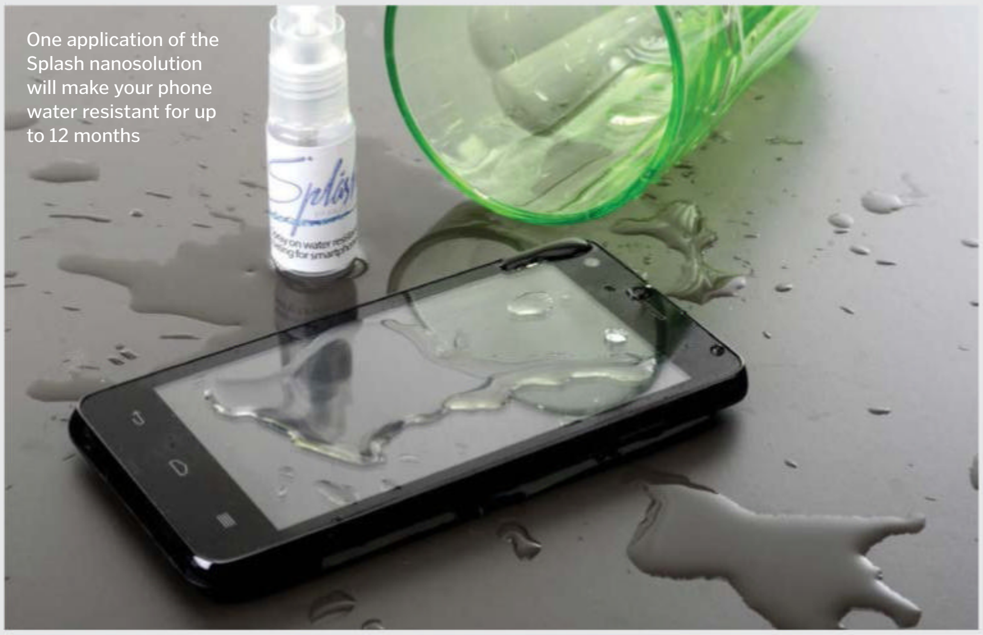
6 Battery power
The direct current, which goes in one direction, can then be used to charge the battery of the device.

Illustration by Adrian Mann

Waterproof your phone

How this amazing spray makes your phone water resistant

Accidentally spilling a glass of water over your phone can cause irreversible damage to the inner workings of the device. Of course, you could attach a waterproof case to make sure it is fully protected, but these often add a lot of bulk to your otherwise slim and sleek phone. However, now you can simply spray on an invisible water-resistant coating that is 1,000 times thinner than a human hair. Splash spray uses nanotechnology to create a small barrier of air around the phone to repel water molecules away from the surface and prevent them from getting inside. All you have to do is spray the openings and buttons on your phone and repeat the process three times, then spray a microfibre cloth and use it to buff the front, back and sides to remove any residue. The spray dries in ten minutes and makes your phone water resistant straight away. It will only protect your phone from spillages, though. Fully submerging your device will still allow liquid to enter the housing, causing damage to the elements inside.



One application of the Splash nanosolution will make your phone water resistant for up to 12 months

© Thinkstock

DID YOU KNOW? *A popular use for the AirBoard is cattle herding as it is a cheaper and safer option than horseback or helicopter*

The AirBoard

Meet the smallest one-person aircraft in the world

Ever wanted to fly but don't have the time or money to train as a pilot? The new AirBoard could be the answer. The smallest one-person aircraft in the world, it can carry the weight of a single person using its powerful battery. The AirBoard is classified as an ultralight quadcopter aircraft and it's small enough to fit in the boot of your car.

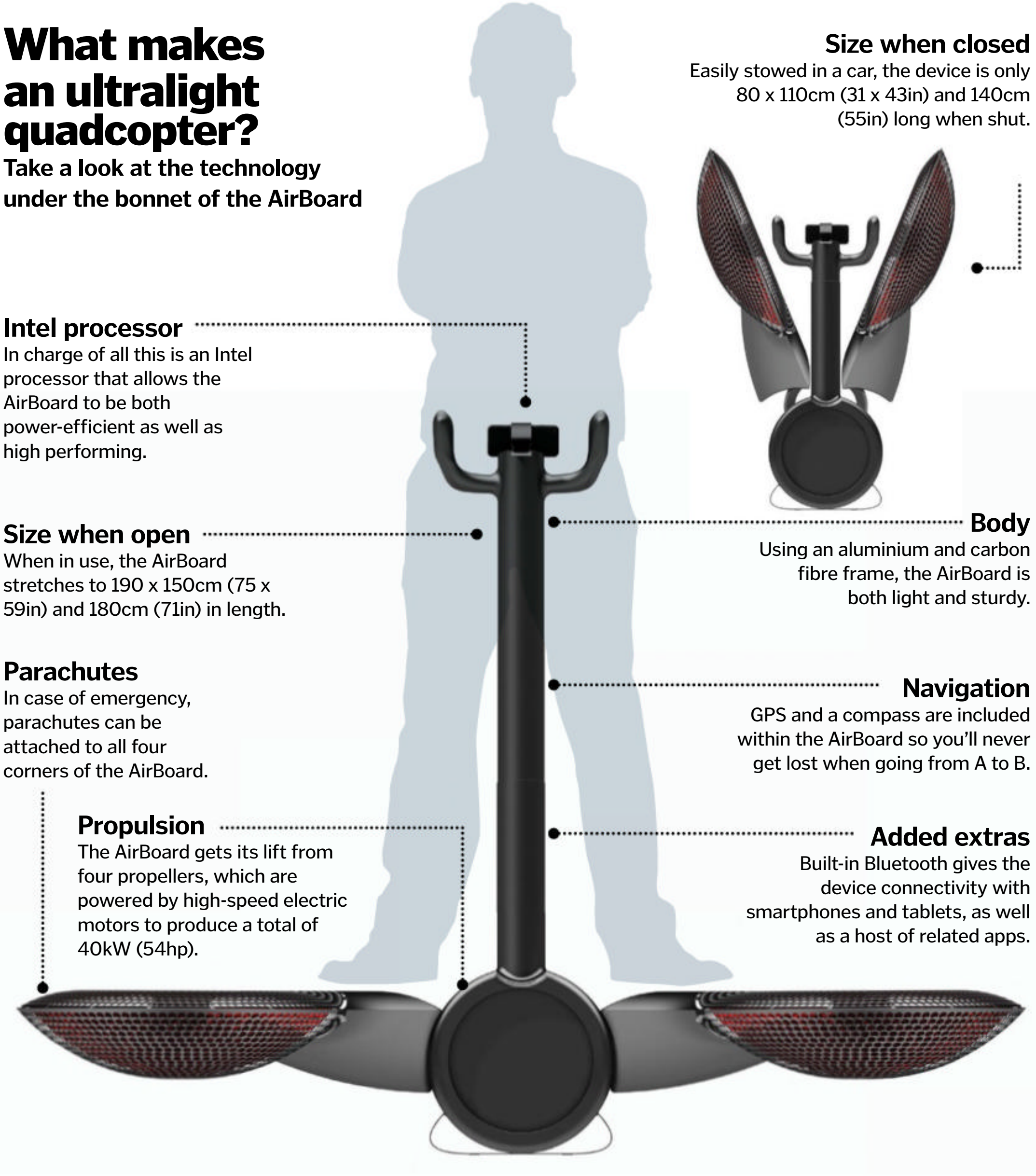
Its thrust is provided by four high-speed electric motors that each power a propeller. The drive system is managed by an Intel processor chip that incorporates a ground collision sensor to keep the board at a set height above the ground.

This system comes into its own when you take the AirBoard into the great outdoors. Designed for both urban and rural use, the quadcopter will hover over nearly all ground, whether it's a snowy plain, water, rocky terrain or just in the street.

The device is easy to control, requiring the user to merely lean in the direction they want to go. For safety, the board's altitude is limited to a tame 1.5 metres (4.9 feet). The AirBoard's qualities make it ideal for recreational use but its features also make it potentially useful in search and rescue for the emergency services and perhaps even espionage for the military.

What makes an ultralight quadcopter?

Take a look at the technology under the bonnet of the AirBoard



Size when closed
Easily stowed in a car, the device is only 80 x 110cm (31 x 43in) and 140cm (55in) long when shut.

Intel processor
In charge of all this is an Intel processor that allows the AirBoard to be both power-efficient as well as high performing.

Size when open
When in use, the AirBoard stretches to 190 x 150cm (75 x 59in) and 180cm (71in) in length.

Body
Using an aluminium and carbon fibre frame, the AirBoard is both light and sturdy.

Parachutes
In case of emergency, parachutes can be attached to all four corners of the AirBoard.

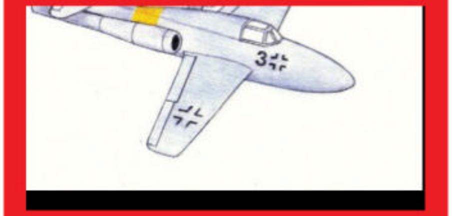
Navigation
GPS and a compass are included within the AirBoard so you'll never get lost when going from A to B.

Propulsion
The AirBoard gets its lift from four propellers, which are powered by high-speed electric motors to produce a total of 40kW (54hp).

Added extras
Built-in Bluetooth gives the device connectivity with smartphones and tablets, as well as a host of related apps.

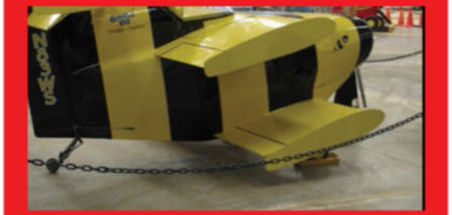
The contenders

More tiny aircraft proving that bigger isn't always better



Messerschmitt Me-328

It may have never made it past the prototype stage, but the Messerschmitt Me-328 is the smallest pulsejet fighter of all time. It would have been used by Nazi Germany as a parasite fighter launched off larger aircraft.



Bumble Bee II

The tiny 2.7m (8.8ft)-long Bumble Bee II is listed by the *Guinness Book Of Records* as the smallest aircraft ever made, but it was sadly destroyed in a crash in 1988.

Bede Bd-5

The Bede BD-5 is considered the smallest civilian jet but not the world's smallest aircraft. Its first flight was in 1971 and despite its 3.8m (12.5ft) length it can reach a top speed of 483km/h (300mph).

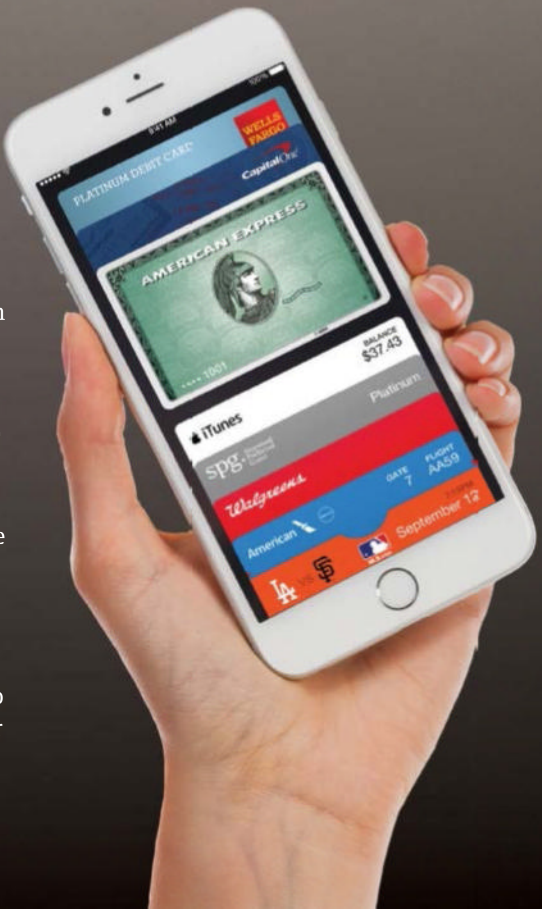
XF-85

A prototype parasite fighter like the Me-328, the American XF-85 Goblin was the world's smallest jet fighter. At 2,050kg (4,519lb) when loaded, it is significantly heavier than the civilian aircraft on the list, mainly due to its four machine guns.

© AirBoard; Thinkstock

MOBILE PAYMENTS

Apple Pay and other touch technology that will revolutionise shopping



Our pockets and bags today are stuffed, straining under the weight of our smartphones, keys, cash, a plethora of credit and debit cards, loyalty cards, travel passes and more. Leaving the house with all of our essential items can sometimes feel like the cruellest memory test. Wouldn't it be a relief to be able to condense it all into one item that fits in the palm of your hand? Turns out, if you own a smartphone with a Near Field Communication (NFC) chip, perhaps you already can.

NFC is a set of wireless standards that enable portable electronic devices with dedicated NFC chips to `talk` via short-range radio waves when held within a few centimetres of each other. This allows them to carry out a multitude of useful functions, including financial transactions, identification, access control and information transfer. Just as magnetic-strip plastic cards revolutionised the way we pay by eliminating the need to carry cash, NFC is set to transform our daily lives by freeing us from our wallets entirely.

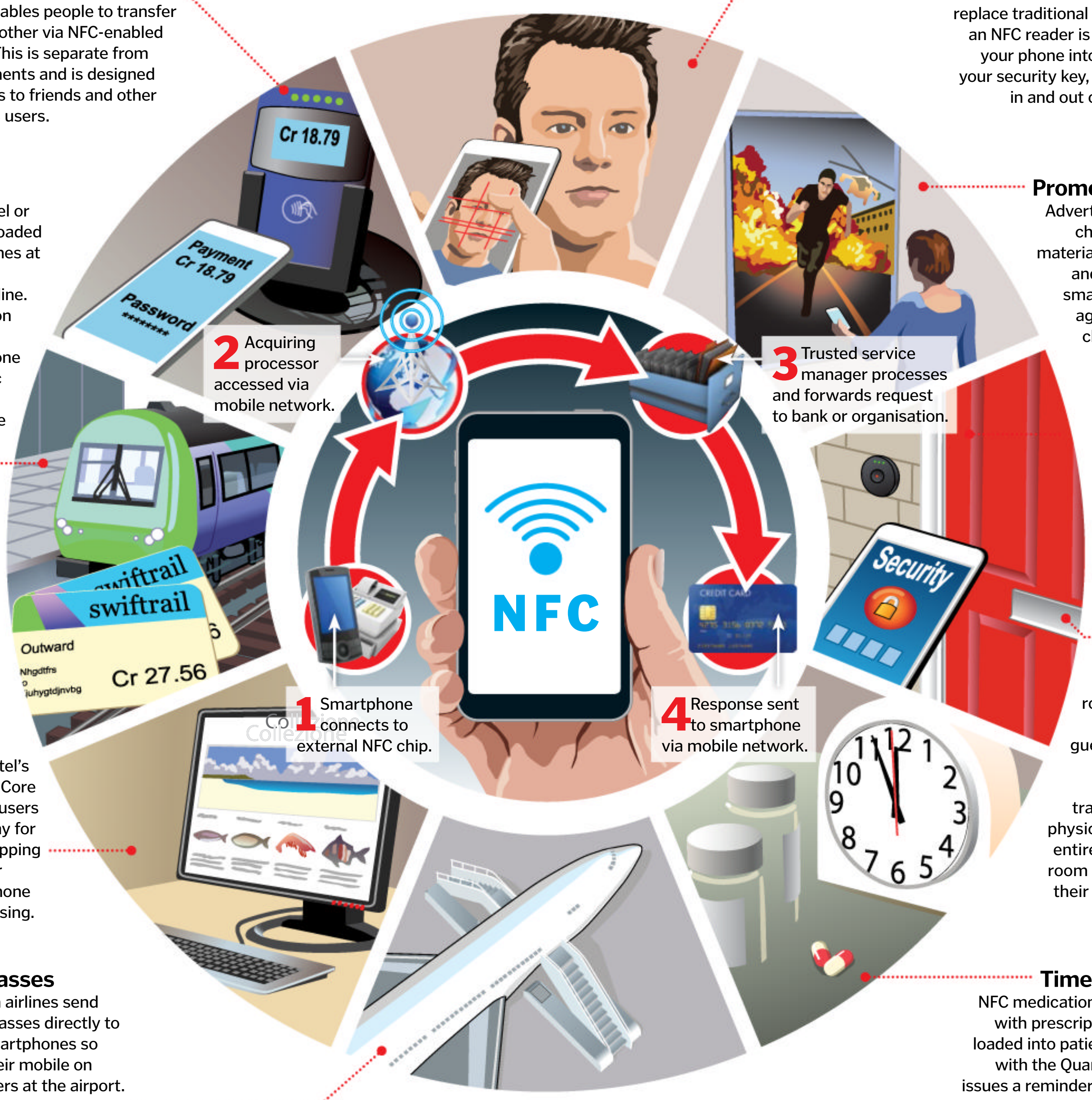
Even if you don't own an NFC phone, chances are you're already familiar with contactless technology. Cities all over the world use dedicated travel cards like London's Oyster, which can be topped up with credit in advance to save ticket-buying time and hassle at the turnstiles. In the last decade, all the major credit and debit card associations have added contactless payment functionality to their cards, allowing cardholders to settle small purchases by simply tapping their card on a payment terminal, removing the PIN verification stage altogether. Some transport services have even brought these two functionalities together, allowing travellers to abandon transport cards and instead pay their way through the turnstiles with contactless bank cards.

But where the contactless revolution is really beginning to gain traction is with NFC smartphones. Coupled with apps like PayPal and Google Wallet – which keep a virtual electronic track of the user's credit and debit cards, loyalty cards and gift cards – they can be

DID YOU KNOW? Oyster cards are used for over 20 million journeys on London's transport system every day

NEAR FIELD COMMUNICATION

NFC isn't just for making payments. Check out all the amazing ways it can streamline our lives



2 Acquiring processor accessed via mobile network.

3 Trusted service manager processes and forwards request to bank or organisation.

1 Smartphone connects to external NFC chip.

4 Response sent to smartphone via mobile network.

Money transfer

PayPal's app enables people to transfer money to each other via NFC-enabled smartphones. This is separate from merchant payments and is designed for paying debts to friends and other PayPal and NFC users.

Tickets

Tickets for travel or events can be loaded onto smartphones at NFC payment terminals or online. Ticket inspection takes place by tapping the phone to an automatic gate or a handheld device carried by a conductor.

Online shopping

Computers and tablets using Intel's 4th Generation Core Processor give users the option to pay for their online shopping by tapping their NFC-enabled phone against their casing.

Boarding passes

Some European airlines send NFC boarding passes directly to passengers' smartphones so they can tap their mobile on dedicated readers at the airport. This works even if the phone's battery is dead.

Identification

NFC-enabled smartphones can replace traditional ID cards wherever an NFC reader is installed – turning your phone into your library card, your security key, your pass to clock in and out of work, and more.

Promotional codes

Advertisers can use NFC chips in promotional materials such as posters and stickers. When a smartphone is tapped against one of these chips, details of the deal load in the phone's web browser.

Security access

Hotels can send room access rights in advance to guests' NFC-enabled smartphones, allowing weary travellers to skip the physical check-in phase entirely and enter their room by simply tapping their phone to a reader on the door.

Timed medication

NFC medication labels embedded with prescription details can be loaded into patients' smartphones with the Quand app. The phone issues a reminder when it's time for a dose and requests a scan of the package as confirmation.

How Near Field Communication works

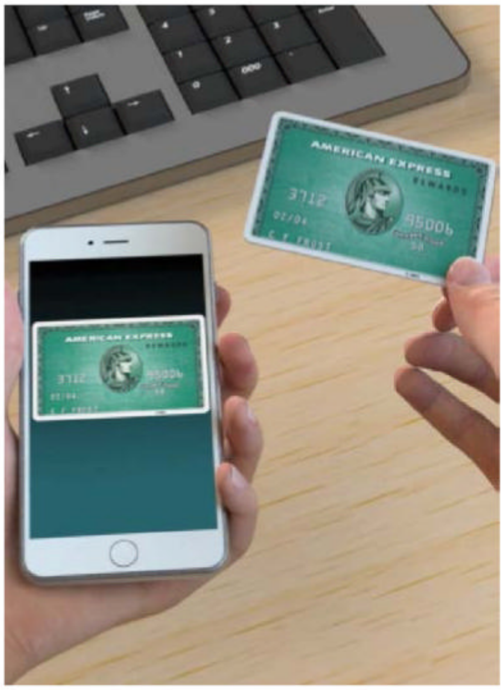
The technology is identical to that employed in contactless card payments, but the term NFC is generally used to refer to applications for smartphones. NFC devices fall into two categories: active and passive. Passive devices, like NFC tags or stickers, contain readable information but don't read any information themselves.

Active devices like smartphones and credit card readers have their own power supply and can read and transmit information, meaning that they can exchange data with other compatible devices. Two-way communication between a pair of active devices offers added payment security, as various requests and authentications are exchanged back and forth.

NFC works by short-range electromagnetic induction. The chip inside your phone is comprised of a secure microcontroller, protected memory, and a small antenna. When an electrical current passes through it, a magnetic field is set up, which in turn induces a current in the nearby device's chip. Data is exchanged via these electrical impulses.

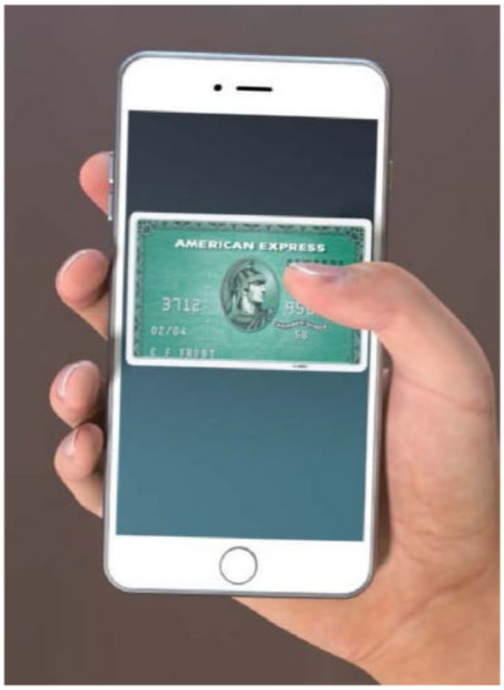
HOW APPLE PAY WORKS

Discover how the iPhone 6 combines NFC, Touch ID and built-in security



Loading payment cards

1 Cards are loaded into the iPhone's Passbook app either by scanning with the camera or by typing details in manually. Each new card must be confirmed separately with the issuing bank to activate payment information links.



Selecting a card

2 To make a purchase, the shopper selects the card they want to use from within Passbook. Each stored card has been assigned a unique 16-digit Device Account Number, an encrypted token used in place of the real card number.

Identity protection

3 Unlike handing over a plastic payment card, when a shopper chooses to pay for their goods or service using Apple Pay, their personal identity and card number are kept completely private.

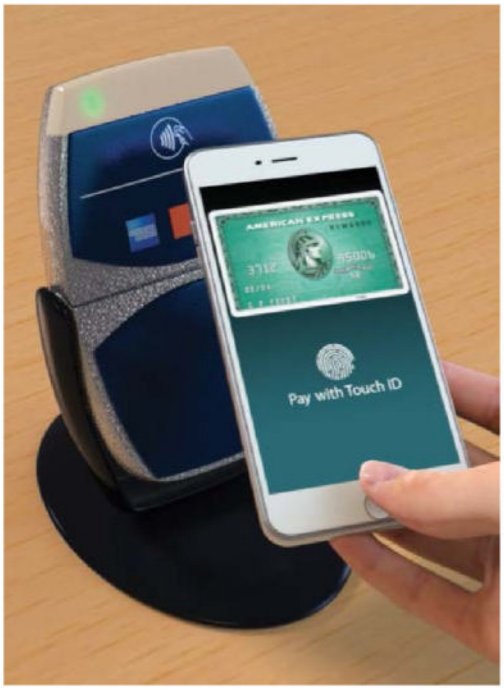
AMERICAN EXPRESS
Pay with Touch ID

Authorising payment

4 The shopper taps their iPhone – with card selected – to the merchant's NFC payment terminal and authorises the payment by placing their finger on their phone's Touch ID fingerprint scanner.

Touch ID confirmation

5 Successful Touch ID authentication prompts the iPhone's Secure Element chip to release the card's unique Device Account Number, along with a transaction-specific dynamic security code that is used to process the payment.



Purchase completed

6 Confirmation that the transaction has been processed appears on screen and a subtle vibration and beep lets them know the transaction is complete. This is useful if the shopper has already pocketed their phone.

DID YOU KNOW? *Half of the world's mobile transactions take place in Kenya; M-Pesa provides millions with banking access*

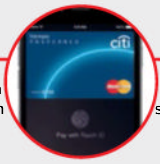
KEY DATES
CONTACTLESS EVOLUTION

1995
The Seoul Transportation Card is the first contactless smartcard to be used for electronic ticketing.

1997
ExxonMobil introduces SpeedPass, a contactless petrol payment system, and garners over 6 million users.

2003
MasterCard launches PayPass contactless payment cards – followed by American Express ExpressPay, Visa payWave and Discover Zip.

2011
Google and MasterCard team up to launch Google Wallet, an Android app that facilitates NFC smartphone payments.

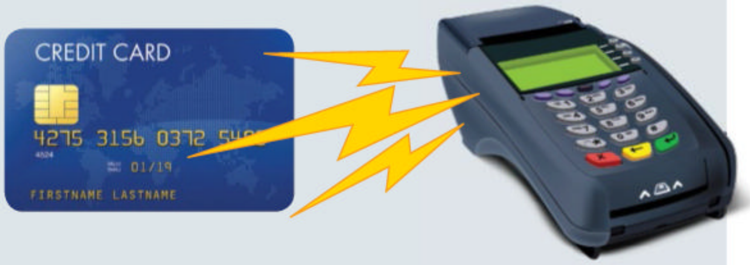


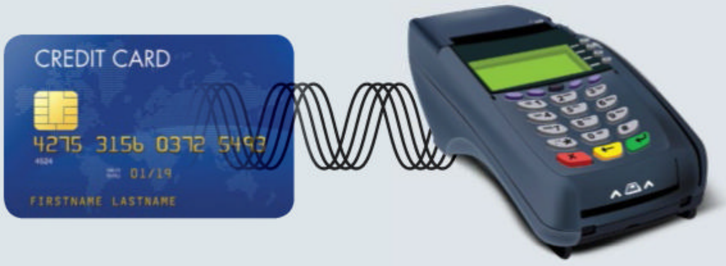
2014
Apple Pay is the first smartphone payment system to combine NFC with Touch ID fingerprint scanning.

ANATOMY OF A CONTACTLESS CARD TRANSACTION

Contactless lets you pay sums of up to £20 or $25 without entering your PIN

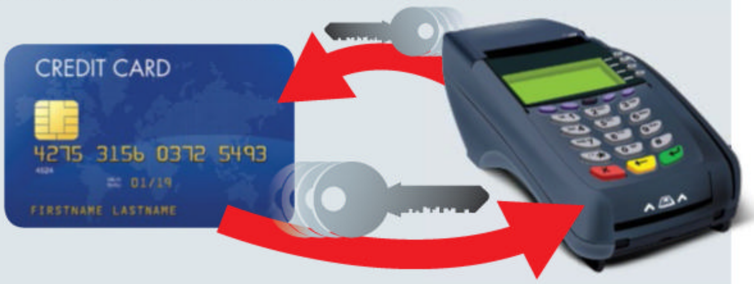
Energising
The card reader emits high-frequency radio waves, which energise the card by electromagnetic induction when it is brought within a few centimetres of the reader.

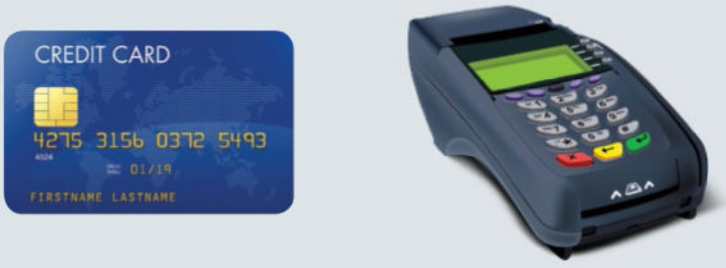




Radio connection
Embedded in the card, the contactless smart chip is wired to an antenna. Once the chip is powered on, a radio connection is established between the chip and the reader.

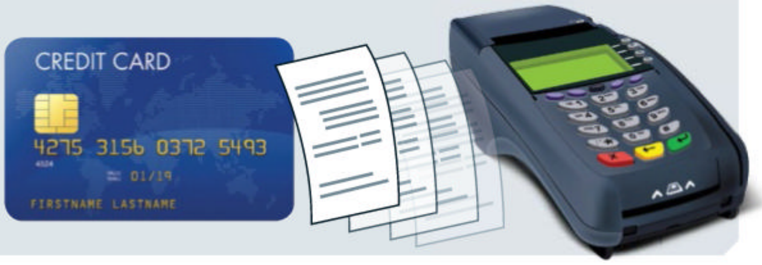
Encryption key exchange
The reader sends the card an encryption key, according to a private key known only to the card issuer. The card decrypts the key, allowing all future communication to take place using this key.





Transaction
The reader sends transaction details to the card, which uses another secret key – unique to the card – to generate an authentication code that authorises and exclusively identifies the transaction.

Completion
The card encrypts the transaction details with the card issuer's key before transmitting them to the reader; the reader returns a receipt to the card for storage.



used like contactless cards at the checkout (with PIN) transport hub, to swiftly pay for items online, and even allow individuals to transfer money instantaneously to one another by touching their compatible phones.

Yet despite these promises of speed, streamlining and simplicity, contactless payment hasn't really taken off. According to a 2014 survey by Thrive Analytics, although 78 per cent of respondents had heard of digital wallets like PayPal, only 32 per cent had ever used one. The main reasons they cited for their hesitance were concerns over security and the belief that – once you've pulled out your phone, unlocked it, accessed a payment app, and typed your PIN into the merchant's terminal – the time saving over traditional payment methods is overstated.

Learning to trust the safety of NFC payments may be just a matter of time and familiarisation. Indeed, once a connection has been established with a vendor's card reader, the steps used to process contactless payments are identical to those that process millions of magnetic-strip transactions securely every day. Contactless transactions have the advantage that the buyer's name and card number are kept completely private; the NFC chip encrypts all sensitive information before sending it, rendering it useless for any fraudulent transactions.

As for the second problem, Apple's newly launched Apple Pay app offers a neat solution: Touch ID fingerprint scanning. Once they've registered their cards and selected a default, Apple Pay users can authorise payments with just a single touch. Apple have a solid track record of dragging niche products firmly into the mainstream, and industry experts predict Apple Pay will have a game-changing impact on the uptake of mobile payments over the next year.

For businesses like OpenTable – an online restaurant-booking service that seats over 15 million diners per month at over 32,000 restaurants across North America, the UK, Japan and Germany – mobile payments represent an exciting new way to serve their customers. It removes the hassle of flagging down a member of a restaurant's waiting staff in order to settle the bill. The company rolled out its own mobile-payment scheme in San Francisco and New York in 2014, and one-touch Apple Pay offers a way to "make [the] payment experience even more intuitive and seamless", according to CEO Matt Roberts. Expect more businesses to follow suit in the near future. ✸

© Dreamstime; Art Agency; Vybr8

Inside the GoPro HERO4 Session

Take a look inside the smallest and lightest action cam yet

GoPro has quickly become synonymous with action cameras, letting extreme sports fans capture their stunts from dynamic new perspectives. The latest model in the line-up, the GoPro HERO4 Session, makes this even easier thanks to its tiny yet rugged frame. Weighing just 74 grams (2.6 ounces), the Session is 50 per cent smaller and 40 per cent lighter than other GoPro HERO4 cameras because it doesn't need a separate protective housing to make it waterproof.

The camera is completely watertight, enabling it to be used underwater at depths of up to ten metres (33 feet). Plus, without a bulky case to get in the way, the dual microphones are able to pick up higher-quality audio and the camera can automatically switch between the front and back microphones to capture the best sound with reduced wind noise.

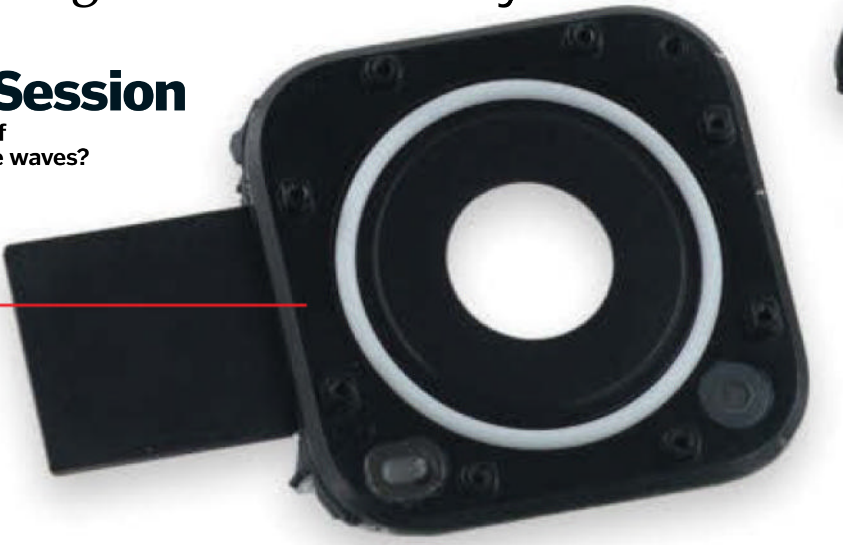
The cube-shaped camera is compatible with most existing GoPro mounts, so it can be attached to a helmet, bike, surfboard and more. It also comes with a new ball joint buckle mount, that lets you instantly tilt and rotate the camera by 360 degrees, while auto image rotation ensures your footage is the right way up.

With only one button, the Session is very easy to control, yet still features a wide range of shooting options, from top quality 1440p-resolution video to slow-motion capture at 100 frames per second. You can also shoot still images too, with time-lapse mode for capturing slow-changing scenes and burst mode for fast-paced action.

The Session automatically adjusts its capture orientation if you accidentally mount it upside down, so your footage is always the right way up.

Inside the Session

How does this waterproof camera work beneath the waves?



O-ring
This waterproof seal protects the lens and other internal components beneath the removable lens cover.

Communication chip
Bluetooth and Wi-Fi connectivity enable the camera to be controlled via a GoPro remote or a free app on your smartphone.

GoPro
Rechargeable Li-ion Battery Pack
3.8V ⎓ 1000mAh 3.8Wh
601-06750-000
CHDHS-101

Battery
The fixed rechargeable lithium-ion battery lets you record high quality video for up to two hours on a full charge.

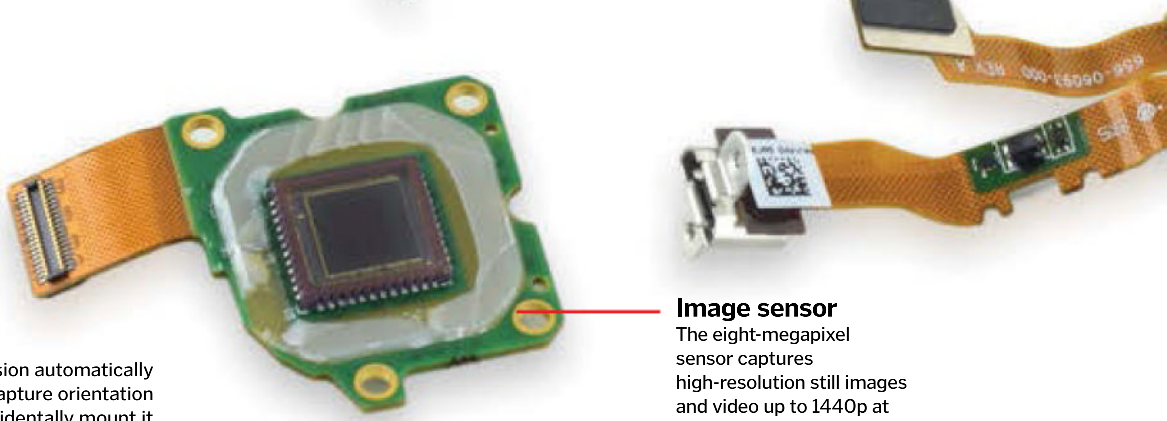
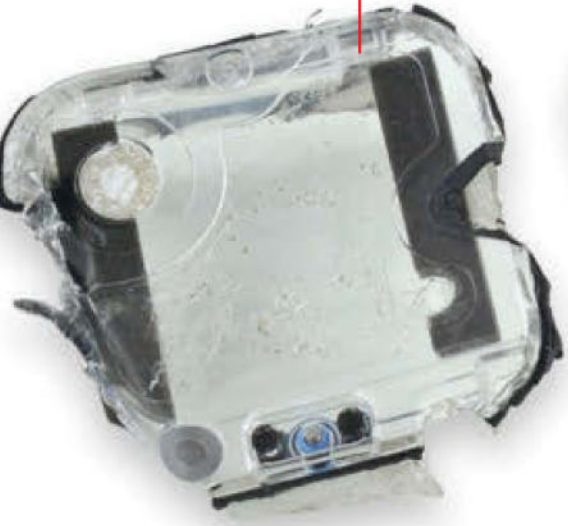


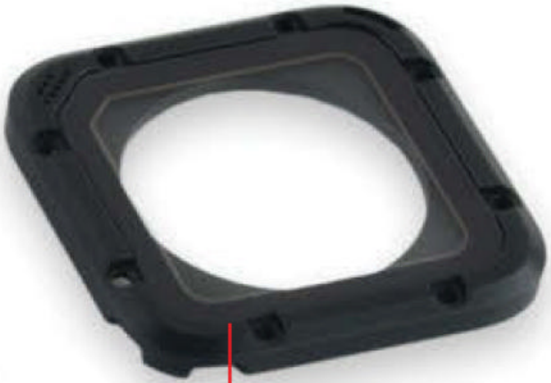
Image sensor
The eight-megapixel sensor captures high-resolution still images and video up to 1440p at 30 frames per second.

DID YOU KNOW? *The first GoPro, launched in 2004, was a 35mm film camera; the digital version went on sale in 2006*

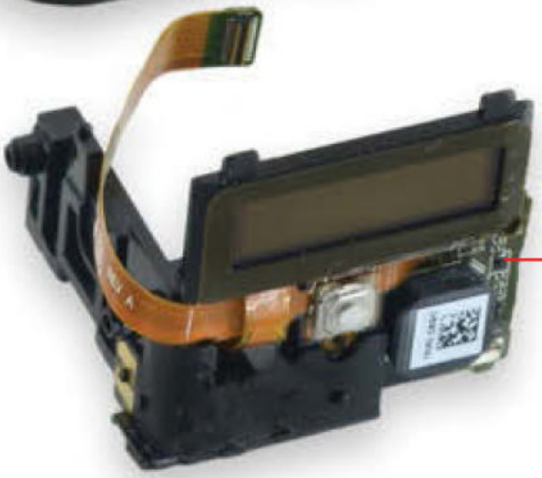
> *"The Session is very easy to control, yet features a wide range of shooting options"*

Waterproof casing
An outer rubber cover is glued to an inner plastic casing to provide watertight protection for the internal components.

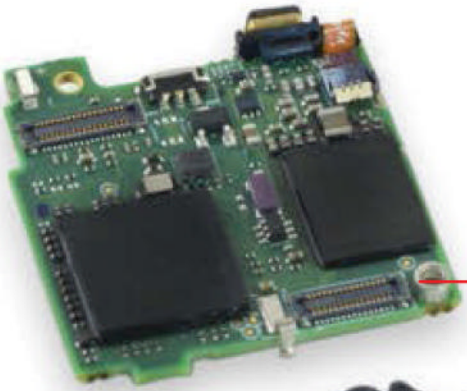




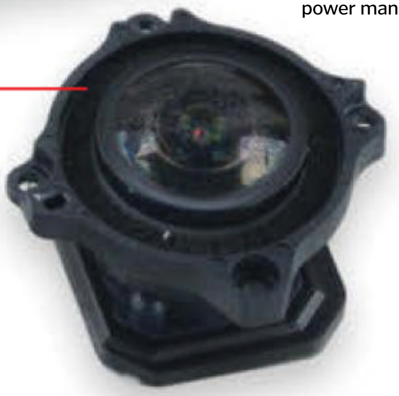
Lens cover
If it gets damaged, the glass lens cover can be unscrewed for replacement or repairs.



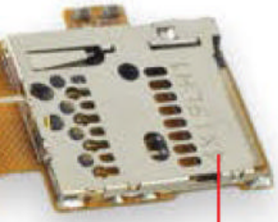
External controls
A single button powers the camera on and off and starts and stops recording, plus a small backlit display indicates the recording mode.



Motherboard
This chip houses the image and video processor, in-camera memory and power management unit.



Lens
The all-glass lens provides an ultra-wide angle field of view but with reduced distortion to combat the fish-eye effect.



Connection ports
Sealed behind a hinged door, the microSD slot allows footage to be stored, and the micro-USB port is for charging and file transfer.

Top Stats

Weight: 74g (2.6oz)	
Megapixels: 8MP	
Price: £329.99 / $399.99	
Dimensions: 35 x 35 x 35mm (1.4in)	
Waterproof: Up to 10m (33ft)	
Field of view: 170 degrees	

Capture the action

Ride the waves

The surf edition of the Session comes with a surfboard mount and camera tether, so you can safely use it on the ocean waves. There's also an optional Floaty accessory that will stop the camera from sinking if it does come loose.

Personal perspective

The camera's small, cube-shaped design and supplied low-profile frame mount means you can wear it as close to your eye-level as possible. This helps you capture your own unique view of the action to keep and share.

Get creative

As well as being able to record high quality video at regular speed or in slow motion, you can also capture a burst of still images at ten frames per second, or create a time lapse video by shooting at intervals ranging from 0.5 to 60 seconds.

© GoPro; iFixit

>1 exabyte
Estimated data now stored in the cloud

Apple's North Carolina iCloud data centre uses as much power as **14,000** households

66% of Brits use the cloud without even realising it

By 2015, end-user spending on public cloud services could be over **$180 billion**

CLOUD STORAGE

Your ultimate guide to cloud computing

"The cloud" is a major buzzword in computing right now, but its meaning is rather, well, cloudy for most people. Nevertheless, chances are high that you've already used the cloud, even if you may not have known it at the time. Media sharing services like Flickr, Instagram and YouTube? They use the cloud. Webmail clients like Gmail and Hotmail? Banking apps? Those too. Read on and we'll see if we can't dispel the fog a little…

At its heart, cloud computing involves using the power of the internet to outsource tasks you might traditionally perform on a personal computer – anything from handling simple storage to complex development and processing – to a vast and powerful remote network of interconnected machines.

This outsourcing is handy for the casual user who is fed up of having to free up space on their hard drive or purchase new storage for all the cat/baby/food photos they can't stop taking. It's even better for businesses that want to use the cloud for processing and storage – because users only pay for what they use.

Think about it. Back in the day, companies purchased computing infrastructure based on what they figured they might need now and in the next couple of years. Fearing what would happen if they underestimated demand, they tended to over-buy only to then have the equipment sit around idle. Not only that; business software is expensive. Not to mention the servers, networks, bandwidth, power, cooling, office space, and the experts needed to install, configure and run the whole caboodle.

Cloud computing allows businesses to run essential programs and applications through the Internet, saving them time, space, hassle and lots and lots of money. Billing for cloud services works just like the way you pay for utilities like gas and electricity in your home; it's pay-as-you-go. The cloud is also extremely flexible. For heavy tasks, clients have instant access to scaled-up computing power on the fly. When they're done with it they simply release it back to the cloud.

DID YOU KNOW? *A new server is added to the cloud for every 600 smartphones or 120 tablets*

What is the cloud?

The first thing you need to know is that "the cloud" exists in far-flung data centres, which you access via the internet. It is a collection of networked computer hardware that works together to provide many aspects of computing in the form of online services. You can't physically touch the hardware itself in the public cloud, but you control it remotely via web interfaces.

One of the central features of the cloud is virtualisation. Virtual machines are created with software that subdivides the computing power, memory and storage of a given machine into multiple smaller units, each running their own operating system. This virtualisation allows computing resources to be shared and allocated efficiently across the cloud.

Cloud computing is a general term that is better divided into three categories: Infrastructure as a Service (IaaS) – where big players like Amazon and Google rent out immense computing infrastructure to other companies; Platform as a Service (PaaS) – online spaces where developers create online applications for specific sets of users; and Software as a Service (SaaS) – where clients use software over the internet.

Even the average web surfer at home has interacted with at least some of these. Facebook, Twitter and Gmail are all examples of SaaS cloud applications. One of the things that make it so powerful is the fact that – in the case of the former two – thousands, even millions, of people can interact with the same bit of information simultaneously.

The other giant boon for individual users is that services like Dropbox and Apple's iCloud allow them to store their photos, email, music, calendars, contacts and other data in a central location, accessible from whatever device happens to be handy. These can be set up to automatically sync with the cloud, ending an era of fumbling with USB cables and cursing yourself for bringing the wrong data stick to a meeting. Relax! That appointment you just noted in your phone will appear seamlessly in your desktop calendar, leaving you free to kick back and enjoy the music you're streaming from your collection on distant servers. ▶

Heavy computer processes are often made faster by the help of the cloud's processing power

450 million
Registered users on Apple's iCloud

Cloud storage vs cloud computing

Cloud storage involves stashing data on hardware in a remote physical location, which can be accessed from any device via the internet. Clients send files to a data server maintained by a cloud provider instead of (or as well as) storing it on their own hard drives.

Dropbox, which lets users store and share files, is a good example. Cloud storage systems generally encompass hundreds of data servers linked together by a master control server, but the simplest system might involve just one.

Cloud computing also involves clients connecting to remote computing infrastructure via a network, but this time that infrastructure includes shared processing power, software and other resources. This frees users from having to constantly update their software and systems, while allowing them to harness the processing power of a vast network. Familiar everyday services powered by cloud computing include social networks like Facebook, webmail like Gmail, and online banking apps.

14 million
Jobs cloud computing will create by 2015

Cloud jargon buster!

1 Server
A computer that processes requests and delivers data to client computers over a local network or the internet. Typically configured with extra processing, memory and storage capacity, it enables clients to share data and resources with others.

2 Data centre
A purpose-built facility that houses cloud infrastructure such as servers, storage systems and networking.

3 Virtualisation
Where individual servers are fooled into thinking they're multiple servers with independent operating systems – a trick that reduces the need for more physical machines.

4 Redundancy
The additional machines built into cloud-computing systems to make back-ups and cover in the event of a failure in the systems' main machines.

5 Elasticity
The characteristic that allows cloud systems to automatically scale up or down the provision of resources to meet current demand.

6 SaaS (Software as a Service)
Software or applications that are accessed over the internet and require no end-user installation. Examples include webmail services like Gmail.

7 PaaS (Platform as a Service)
A tool-rich environment where software developers can create, customise, test and deploy new applications.

8 IaaS (Infrastructure as a Service)
Computing infrastructure such as memory, storage, processing and networking, which users purchase based on consumption instead of having to buy hardware outright. Distinct from physical hosting, where customers purchase a physical server in a data centre.

Where's my stuff?

Two words: data centres. Anything you've uploaded to the cloud, or that you run from the cloud, exists on dedicated servers and storage volumes housed in vast warehouses, often situated on campuses full of such warehouses. Data centres are owned by cloud service providers, who are responsible for keeping the servers up and running.

The job of all data centres, however big or small – and yes, some of them can be tiny – is to keep your data physically safe from theft and destruction, and to make sure it's available whenever you want to access it. They run extensive cooling systems to keep the electronics from overheating and have at least one backup generator in case of power outages.

Once you've put your data in the cloud, it may be physically stored in many different places, countries or even continents, depending on where the service provider's data centres are located. In fact, cloud providers actually make multiple copies of the data you upload and purposely store these in disparate locales to ensure that it won't get destroyed or be inaccessible in the event that a natural disaster takes out one of the centres.

The physical location of their stored data is irrelevant to the majority of people, since it can be called together over the internet almost instantly. But for organisations using the cloud for certain sensitive types of data – government documents or health records, for example – understanding where the data is headed and which data-protection and privacy laws apply in those places becomes critical.

How safe is the cloud?

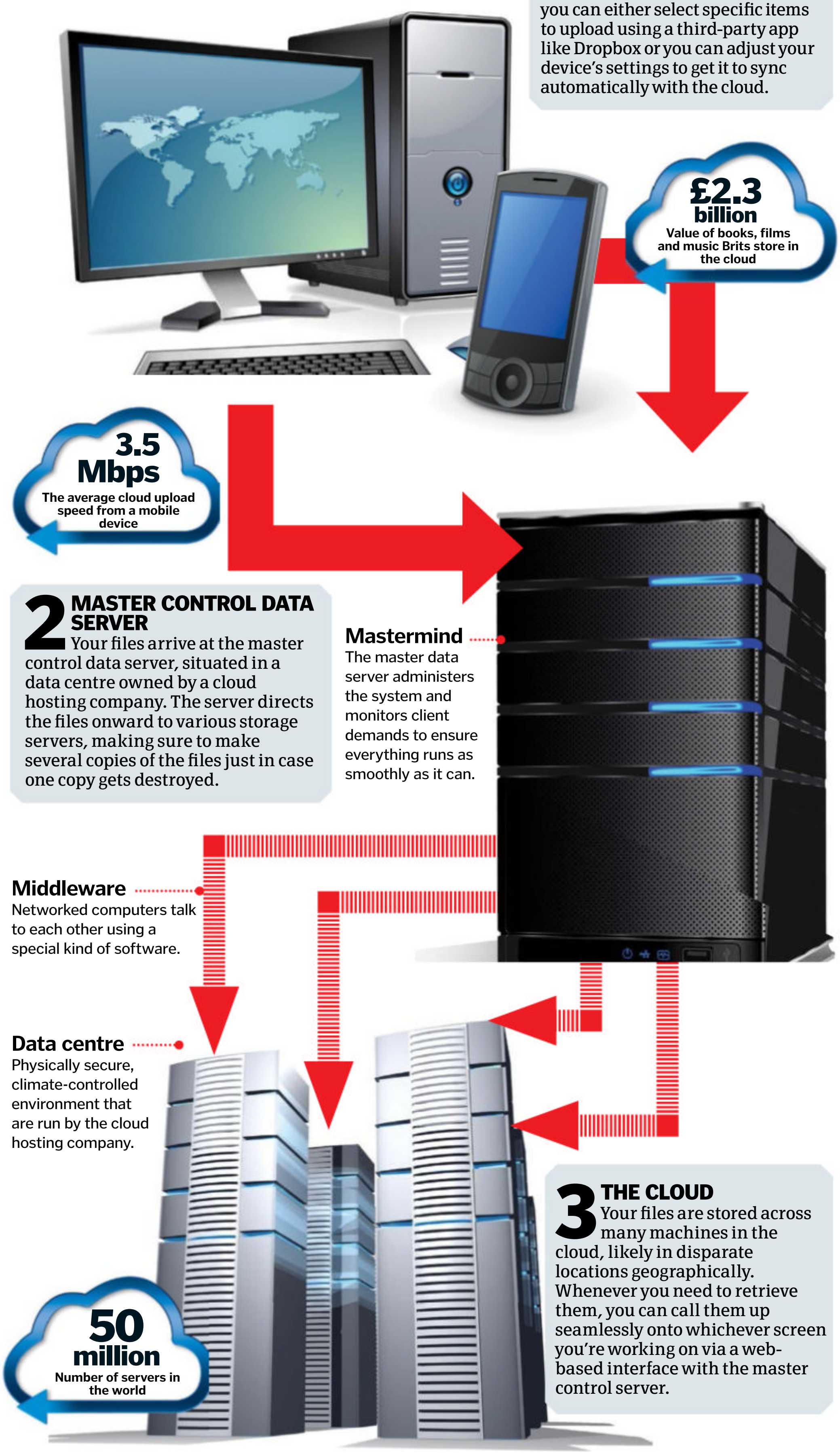
The cloud may promise to lift the burden of our ever-increasing data storage needs, but how do we know our data is truly safe when we entrust it to a cloud provider? What measures do they take to address our two biggest concerns: reliability and security?

We've already learned that cloud providers store backups in multiple locations. Systems that detect smoke, suppress fires and provide emergency power are also standard features of data centres, and these secret locations are heavily reinforced, guarded and internally protected to prevent intruders or disgruntled employees from physically harming or stealing the storage hardware.

To secure your data so no one else can get at it, cloud systems use authentication processes like usernames and passwords to limit access, and data encryption (see boxout below) to protect data that is stolen or intercepted en route. And yet, passwords can be hacked; often it's the service provider who holds the encryption keys

Head in(to) the clouds

Where do your photos, appointments, and music actually go when they leave your phone?


£2.3 billion
Value of books, films and music Brits store in the cloud
3.5 Mbps
The average cloud upload speed from a mobile device
50 million
Number of servers in the world

1 DEVICE UPLOAD Keeping your data backed up, neatly organised and accessible on the go is easy. From your cloud-enabled smartphone, you can either select specific items to upload using a third-party app like Dropbox or you can adjust your device's settings to get it to sync automatically with the cloud.

2 MASTER CONTROL DATA SERVER Your files arrive at the master control data server, situated in a data centre owned by a cloud hosting company. The server directs the files onward to various storage servers, making sure to make several copies of the files just in case one copy gets destroyed.

Mastermind
The master data server administers the system and monitors client demands to ensure everything runs as smoothly as it can.

Middleware
Networked computers talk to each other using a special kind of software.

Data centre
Physically secure, climate-controlled environment that are run by the cloud hosting company.

3 THE CLOUD Your files are stored across many machines in the cloud, likely in disparate locations geographically. Whenever you need to retrieve them, you can call them up seamlessly onto whichever screen you're working on via a web-based interface with the master control server.

DID YOU KNOW? *A 2012 survey found 51% of Americans wrongly believe stormy weather can interfere with cloud computing!*

to your data, meaning that rogue employees could access it; and your data isn't immune to search and seizure by government entities.

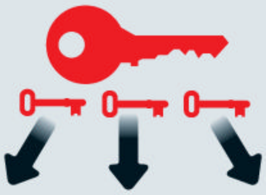
So, to entrust or not to entrust? In any case, you can rest assured that – since cloud storage companies live and die by their reputation – they take great pains to employ the most advanced security techniques and provide the most reliable service possible. But the bottom line is that we live in an age where national governments have been exposed for tapping into supposedly private cloud data. Savvy surfers would be wise to keep anything truly sensitive stored on their personal computer or private cloud behind a firewall, and never upload it to the public cloud.

1.5 million
Requests Amazon's S3 storage service processes per second

How data encryption works

Public-key encryption uses a combination of cryptographic keys to keep your data safe

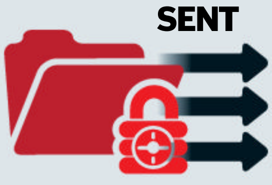
1 Public-private key pair Your computer owns two unique cryptographic keys that are mathematically related to each other: one is public, while one is completely private.



2 Key hand-out It makes your public key freely available to any other computer that wants to send a file to you.

3 Encryption When someone sends you a file, their computer encrypts it with a symmetric key, meaning it can only be opened with the identical key.

4 Public key encryption Both the encrypted file and the key needed to decode it are placed in a file and encrypted using the public key.



5 File transfer The public-key encrypted file is sent to your computer.

6 Decryption step 1 Files encrypted with your public key can only be decrypted by your private key; even if the message is intercepted by another computer that knows your public key, only your computer can decrypt its contents.

7 Extraction Your computer extracts the encrypted file and the symmetric key needed to decode it.

8 Decryption step 2 The computer decodes the file using the symmetric key.

9 File unlock Voila! The contents of the file are now yours to view.

Keeping your data safe

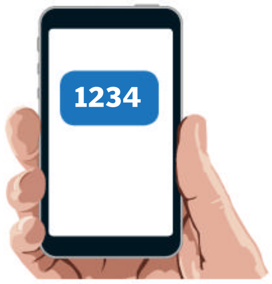
Apple's two-factor verification prevents others from accessing your account, even if they know your password

my.name@icloud.com

••••••••••••••••

Sign in
Whenever you sign into iCloud, or make a purchase in iTunes, iBooks or the App Store, you are asked to enter your Apple ID and password for confirmation.

Added layer
If you're signed up for two-factor, Apple sends a four-digit verification code by SMS or Find My iPhone to one of the trusted personal devices you've registered.



1 2 3 4

Verification
Entering this code into the web browser verifies your identity and completes the sign-in process, allowing you to securely access your account and make purchases as usual.

How was the iCloud hacked?

On 31 August 2014, a cache of almost 200 personal photos of (mostly female) celebrities – many of them explicit – was posted online. *X-Men* and *Hunger Games* star Jennifer Lawrence and recording artist Rihanna were among those whose private pictures, taken on their iPhones and automatically backed up to the iCloud, were stolen and distributed. Following the attacks, one survey found that 20 per cent of respondents had become less confident in the security of the iCloud, while a further 40 per cent were worried about storing photos and data in any cloud service. How was this security breach allowed to happen?

In an interview in the *Wall Street Journal*, Apple CEO Tim Cook dispelled rumours that the victims' user IDs and passwords were taken from the company's servers in a brute force attack. Instead, he explained, the hackers obtained the information via a combination of phishing emails and correctly answering the celebrities' security questions. "That's not really an engineering thing", he commented, but conceded that Apple should have done more to make users savvier about choosing strong passwords and protecting themselves.

Since the scandal, Apple has beefed up its security measures by expanding its two-factor ID verification system (see "keeping your data safe" boxout left) to include any time a new device attempts to access or download iCloud data. Users will also receive an email alert or push notification whenever someone tries to do these things or change the account password. Apple plans to aggressively encourage iCloud users, the majority of whom still haven't yet enabled two-factor authentication, to turn on the feature immediately.

Jennifer Lawrence was one of over a hundred female celebrities to have personal photos stolen from their iCloud accounts

© Dreamstime; Startraks Photos/Rex Features

Fighter pilot helmet of the future

BAE Systems' new combat helmet offers night vision without goggles

Good vision and navigation are two of the most important weapons for a figther pilot. Fighter aircrafts usually have displays built into the windscreen so the pilot can see the information coming from their instruments (speed, altitude, warnings and such) without needing to look down. This might seem a small thing, but if you are in the midst of a dogfight, taking your eyes off your adversary even for a second could be deadly. Rather than using a projector to shine the data onto the windscreen, though, the new Striker II has incorporated the display into the helmet.

A tiny projector shines the data onto the inside of the helmet's visor, directly in front of the pilot's eyes. Not only does this mean the instrument information is always in view but the Striker also uses motion sensors to track where the pilot is looking. This way the pilot is never without the crucial info it needs to fly, but it also improves communication.

BAE has taken advantage of this display technology to incorporate night vision. Night-vision goggles are already used in fighter aircraft, but they have so far been separate goggles that must be put on when needed. On top of that, they are hefty pieces of kit, which can add to the load on the pilot's neck, which is dangerous, and makes it increasingly difficult to the pilot to look around him/herself.

Instead, the Striker II has a compact night-vision camera in the top of the helmet. This keeps the weight of the system in line with the head instead of hanging off the front. The night-vision picture is then combined with the helmet display so the pilot does not need to change over to the goggles and when they look around they have a synchronised view of the outside world, whatever the time of day.

Advanced warfare

BAE Systems' business development manager Alan Jowett on the benefits of Striker II

How does it help the pilot to have a display built into the helmet?

As the display is on the visor it is always visible wherever the pilot looks, which reduces pilot fatigue because they don't need to look down at their instruments. That could mean the difference between targeting or being targeted.

What sort of information is provided to the pilot?

The helmet provides the usual cockpit information, such as speed, altitude and heading, but the display is like a computer monitor and can show anything required by the mission, such as controlling the weapons.

How does the integrated night vision help?

The Striker I had separate night-vision goggles. The weight of these put a strain on the pilot's neck during manoeuvres and could catch on the inside of the cockpit. The new system turns on instantly and provides better manoeuvrability both inside and outside the cockpit.

A fighter-pilot helmet is much more than just a safety feature

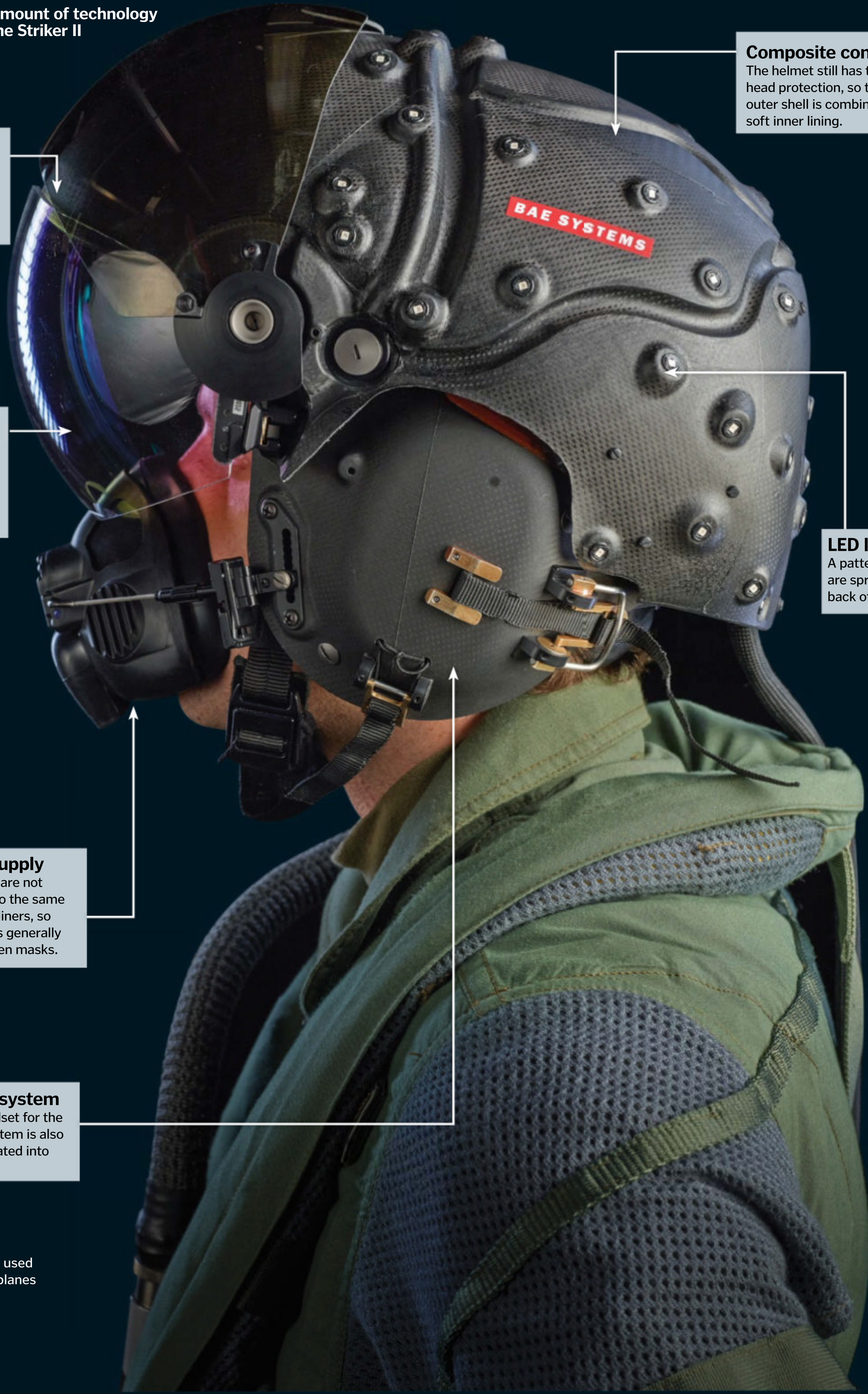
Head tracking and virtual reality

In linking head movement to the display the Striker II is displaying real pictures, in this case from the night-vision camera, as if they were virtual reality (VR). One of the factors that has held up VR is the ability to update the view fast enough for head movement. If there is too much time lag between the movement and the display changing, it causes nausea and undermines the illusion. VR developer Oculus Rift has been working on just this problem and believes that if it can refresh the display at least every 20 milliseconds it will appear smooth to normal human perception.

Oculus Rift has developed a virtual-reality headset for 3D gaming

Under the skin

A tremendous amount of technology is packed into the Striker II



Night vision camera
A tiny digital night-vision camera is mounted above the visor.

Visor
The transparent visor provides both eye protection and the projection surface for the display.

Oxygen supply
The cockpits are not pressurised to the same degree as airliners, so military pilots generally fly with oxygen masks.

Audio system
The headset for the radio system is also incorporated into the shell.

Composite construction
The helmet still has to provide head protection, so the hard outer shell is combined with a soft inner lining.

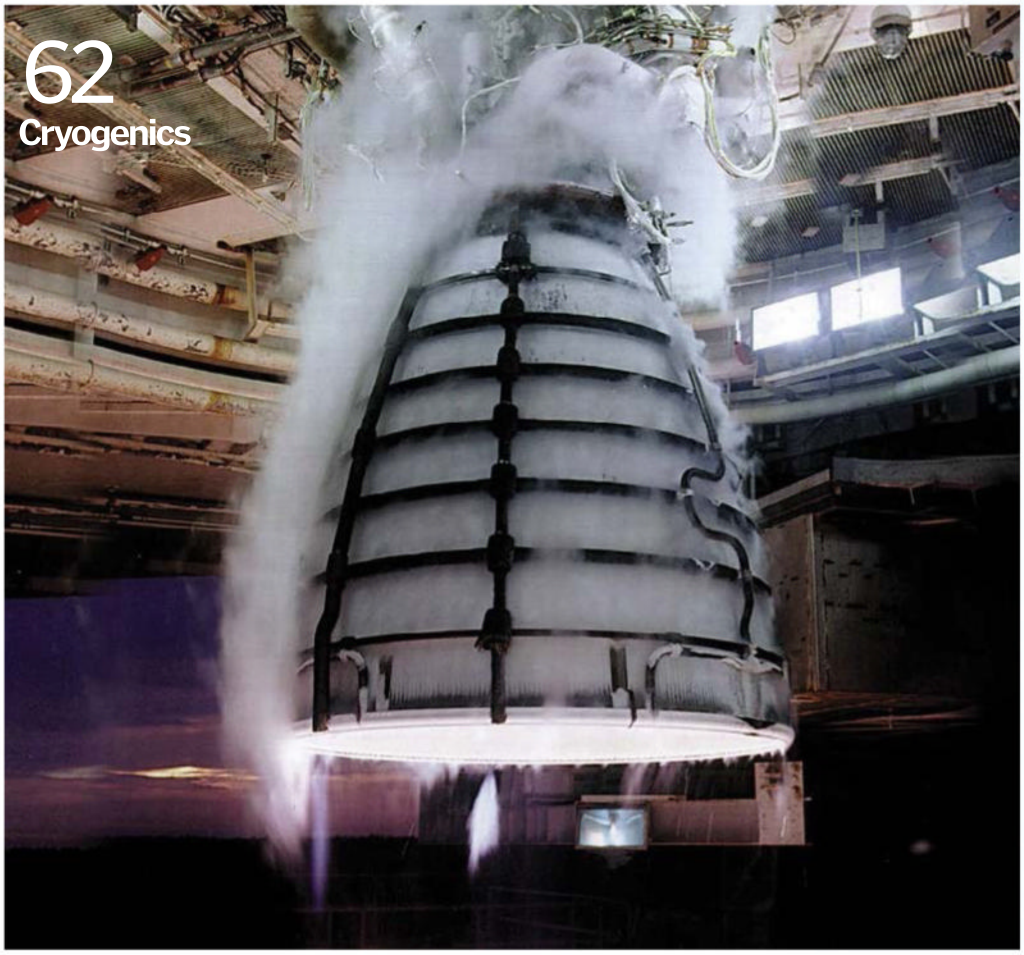
LED lights
A pattern of LEDs are spread over the back of the helmet.

The Striker II can be used in any military aeroplanes or helicopters

© Oculus Rift; BAE Systems

BIOTECH

050
Bionic humans



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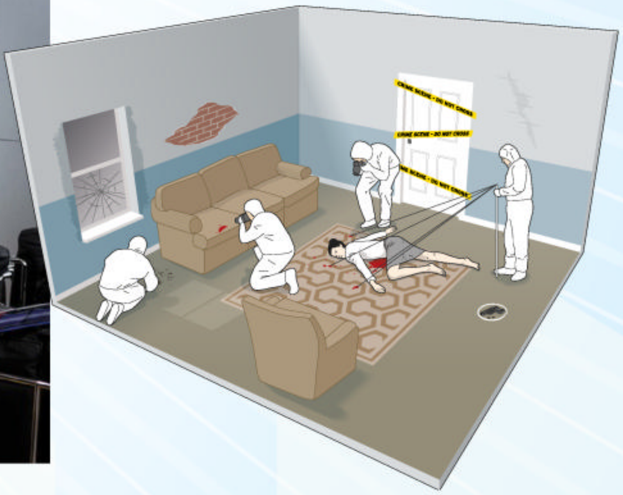
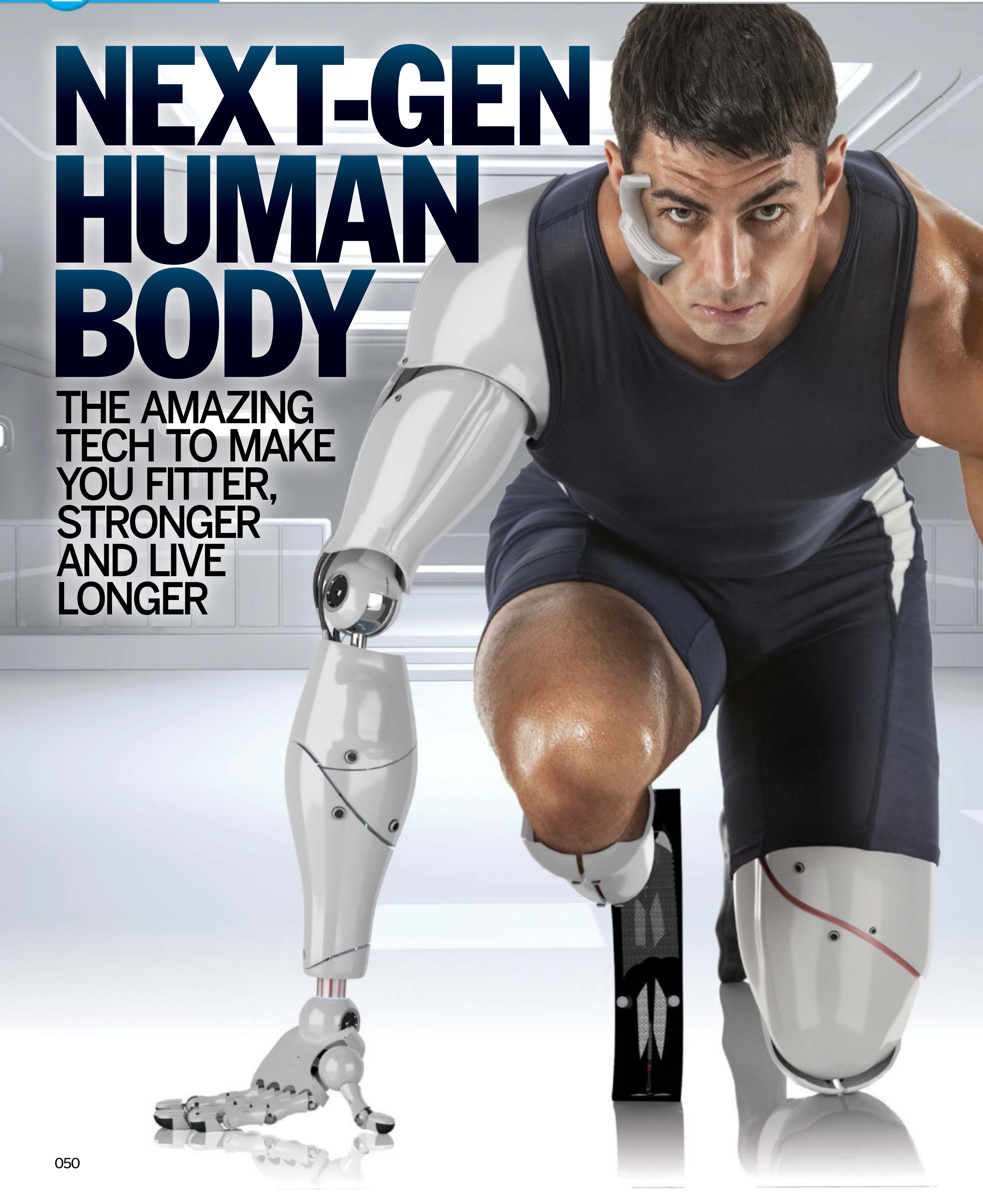
Life-saving tech



NEXT-GEN HUMAN BODY

THE AMAZING TECH TO MAKE YOU FITTER, STRONGER AND LIVE LONGER



Not content with waiting for nature to select humans with the most resistance to deadly pathogens, we developed sanitation, learned about how the immune system works, and invented dozens of vaccinations. We created low-friction implants made from metal alloys and plastics to replace our worn-out joints, implantable pacemakers that can keep our hearts beating, and an arsenal of advanced surgical techniques to repair our bodies when they go wrong. We have completely changed our environments with technology and infrastructure, and in the process we have altered the course of our evolution, defying the rules of natural selection. But have all of our technical advances stopped humans evolving completely?

This is a topic of debate among scientists. In 2013, Sir David Attenborough told the *Radio Times* that he thought humans weren't going to change: "We are the only species to have put a halt to natural selection, of its own free will, as it were." He argued that, because we are now able to ensure that up to 99 per cent of babies survive, the normal processes of natural selection are no longer at play. Some scientists suggest that in our new, human-friendly environment, we are adapting culturally, rather than genetically.

However, in many parts of the world, infant survival is much lower, and many argue that natural selection pressures are still at play. For example, malaria killed an estimated 584,000 people in 2013, according to the World Health Organisation. 90 per cent were in Africa, and most were under the age of five. In areas where malaria is endemic, there is a higher incidence of a genetic disease called sickle cell anaemia, and it is thought that malaria is the driving force behind it. Sickle cell anaemia is caused by a fault in the gene for haemoglobin – the red pigment that carries oxygen in the blood. People with two faulty copies of the gene become very ill, but people with just one copy have some protection against malaria, helping them to survive through to adulthood and pass on their genes.

But what happens in the future? Will there ever come a day when technology becomes so advanced that we are able to defend, enhance and repair our bodies? We delve into the science of the next-gen human body.

How have humans changed?

Humans have a long evolutionary history but even over the last 100,000 years, there have been some significant changes. 60,000 years ago, an average male human would have measured around 1.83 metres (six feet) tall, but 10,000 years ago his height would have been just 1.63 metres (5.3 feet). Changes in climate and the introduction of farming put evolutionary pressure on the human population, and only those best adapted to the new lifestyle survived.

Our environment continued to play an important role in shaping our evolutionary history as people spread out across the world, with different skin colours, face shapes, and hair types proving to have advantages in different environments. Even moving into cities has shaped human evolution; living in close proximity increases the potential for transmission of disease, killing some members of the population before they have a chance to pass on their genes.

Now, with improved diet and health care, humans are starting to get taller again, and vaccinations are able to control at least some infectious diseases. Perhaps surprisingly, our brains are smaller than they once were. We have lost about a tenth of our brain size, and most of the decrease has occurred in the last 6,000 years.

These human skull fragments found in Ethiopia are over 100,000 years old

© Thinkstock; Getty; Alamy

HOW SCIENCE CAN MAKE US SUPERHUMAN

Advances in biology are enabling scientists to modify the human body

Before the age of modern medicine, we were all but powerless to the flaws of the human body, but today we are able to intervene. In some ways, we are already superhuman. Diseases that plagued our recent ancestors are held at bay by vaccinations, and millions of people live with technology implanted into their ears, eyes and hearts. Precision surgery can repair delicate structures inside the body, and genetic techniques are starting to enable us to predict and prevent disease, as well as intelligently design new treatments.

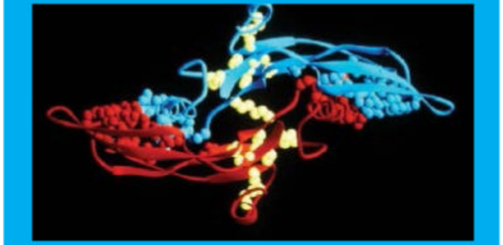
As technology advances, the opportunities to augment our biology are increasing at an unprecedented rate, and the technologies of the future have the potential to take the human body beyond what nature intended. Researchers looking into the science of ageing hope to be able to delay, stall or even reverse the process, and scientists working on repair and regeneration are developing ways to fix damage that would once have been irreversible.

Whether these bold ambitions are actually possible is yet to be seen, but we are gaining more and more control over our own biology, and science continues to have the potential to make us fitter, faster, stronger and smarter than ever before.

The molecule of youth

The secrets of human ageing are sought by scientists across the globe, and some seem to be getting close to the answers. As we age, our stem cells become dysfunctional, and are less able to repair damaged tissues.

Researchers at the University of California, Berkeley have been trying to find out why, and they think that one of the culprits might be a molecule called TGF-beta1. When they used a small molecule drug to block TGF-beta1 in mice, the stem cells in their muscles and brains behaved more youthfully again.



TGF-beta1 is a protein involved in deciding when cells grow and divide

Connecting nerve cells

Stanford University scientists have found what they think is an 'on/off' switch for the growth of new connections in the brain. The molecule, called PirB, sits on nerve cells and normally, nothing happens. But when other molecules stick to PirB, this sends a signal that stops new connections from being made. The team made a decoy version of PirB to catch the joining molecules, switching new synapse formation on again.

If the PirB decoy works in humans, it could be used to restore vision or to help the brain to repair after a stroke

Lab-grown muscles

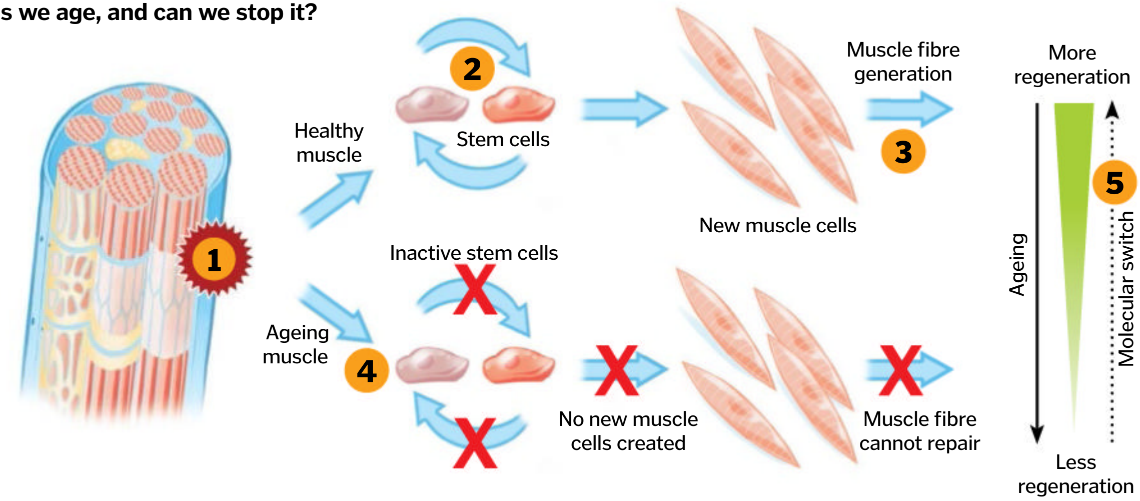
Scientists at Ohio State University and the Center for Gene Therapy at Nationwide Children's Hospital have been looking into the effects of two molecules involved in muscle growth. Myostatin normally limits muscle growth, and follistatin blocks its action, promoting muscle growth.

People and animals with genetic faults in the gene for myostatin have much larger muscles than usual, so the scientists wanted to know whether increasing the amount of myostatin-blocker follistatin would have the same effect. They used gene therapy to deliver follistatin genes to the muscles of monkeys, and their muscles increased in strength and size by around 25 per cent.

Super strength is one thing, but super regeneration might be better. Researchers at Duke University have been developing techniques to grow muscle in the lab, and by paying close attention to recreating the unique environment where stem cells can survive, their tissue is able to repair when damaged. The next step is to find out whether it can get its own blood supply and connect to the nerves of a living recipient.

Reversing the ageing process

What happens to our muscles as we age, and can we stop it?



1. Damage
Damage to the muscle releases chemical signals that alert cells in the surrounding area.

2. Stem cell
Muscle has its own population of stem cells called satellite cells. These can divide to form new muscle cells.

3. Repair
The satellite cells produce new muscle cells, which help to repair the damaged muscle fibre.

4. Ageing
Our satellite cells eventually stop working. They no longer divide in response to injury so muscle can't be repaired.

5. Reversing decline
Scientists in Spain have identified the molecular switch responsible, and found that blocking it in mice allowed stem cells to start repairs again.

DID YOU KNOW? *Before a vaccination was available, 2.6 million people died of measles each year. Now, it is fewer than 200,000*

The future of medicine

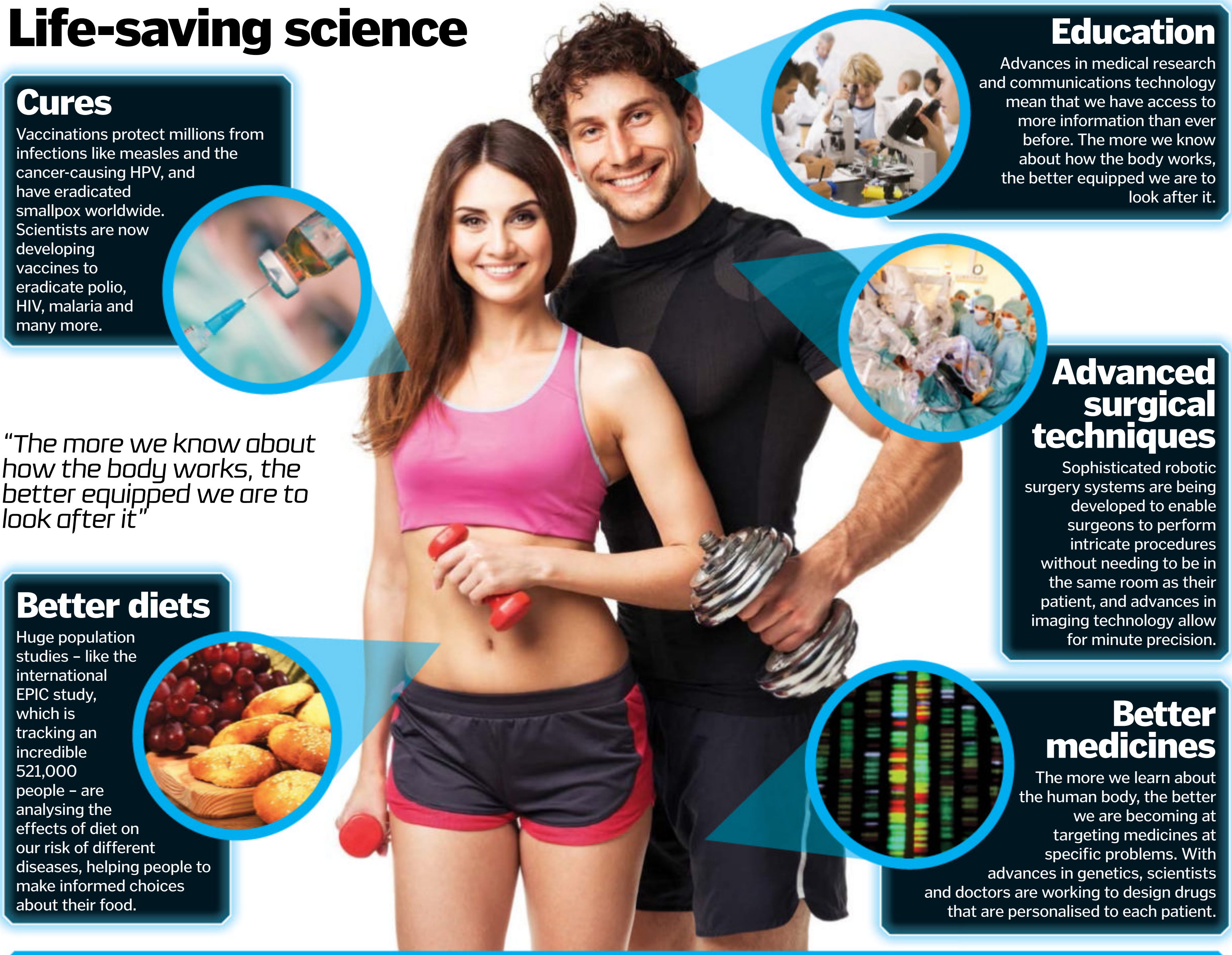
In Britain, average life expectancy hovered around 40 years of age for hundreds of years until the 1800s, when something changed. The Industrial Revolution swept across the nation, and science and technology transformed the way we live our lives.

We have already augmented our reality with sanitation, vaccination, antibiotics, medical imaging, and a whole host of other innovations, and as technology improves and our understanding of the human body increases, there is scope for even more dramatic change.

For example, wearable technology is just getting started, but the gadgets that can currently track steps and heart rate could one day help to monitor all of our vital signs. Biometric sensors are being developed to be worn inside clothes, or to be implanted, and could one day provide real-time feedback and advice on our health.

Technology in the lab is also rapidly changing the way that we design and develop medicines. Using the latest techniques in genetics to identify the underlying causes of disease, scientists are developing precision drugs. In the future, it is hoped that patients will receive treatment based on their own individual genes.

Life-saving science



Cures

Vaccinations protect millions from infections like measles and the cancer-causing HPV, and have eradicated smallpox worldwide. Scientists are now developing vaccines to eradicate polio, HIV, malaria and many more.

Education

Advances in medical research and communications technology mean that we have access to more information than ever before. The more we know about how the body works, the better equipped we are to look after it.

> *"The more we know about how the body works, the better equipped we are to look after it"*

Advanced surgical techniques

Sophisticated robotic surgery systems are being developed to enable surgeons to perform intricate procedures without needing to be in the same room as their patient, and advances in imaging technology allow for minute precision.

Better diets

Huge population studies – like the international EPIC study, which is tracking an incredible 521,000 people – are analysing the effects of diet on our risk of different diseases, helping people to make informed choices about their food.

Better medicines

The more we learn about the human body, the better we are becoming at targeting medicines at specific problems. With advances in genetics, scientists and doctors are working to design drugs that are personalised to each patient.

Changing our genes

Gene therapy, the ability to correct faulty genes, has the potential to be life-changing. However, several scientific and ethical hurdles still need to be overcome.

In the 1990s, scientists developed a virus that – instead of causing illness – could deliver healthy copies of a gene into the bodies of children with Severe Combined Immunodeficiency. Early trials showed that the treatment could successfully combat the disease, but some of the children treated went on to develop leukaemia.

This is because when a virus delivers a gene into a human cell, it slots it into the existing DNA. However, the position it chooses is not always predictable. If the gene is inserted in the middle of a region of DNA that is important, it can lead to serious health problems.

We still have more to learn about the science and technology of manipulating our own genetics, but in the future changing our genes will become much easier. However, the consequences of this kind of scientific advance are unknown, and there is great academic, ethical and political debate about whether manipulating our genetics, or those of our unborn children, is wise.

Huge international projects are underway to untangle the links between genetics and disease

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AUGMENTED HUMANS

What does the future look like for bionics and prosthetics?

In the early days of bionic body parts, scientists struggled to match even the basic functions of the human body, but as technology evolves, it is becoming clear that one day bionics could outstrip our natural capabilities. Will there ever come a day when people are willing to part with perfectly healthy limbs or organs to upgrade to a man-made alternative?

High-tech prosthetic limbs can now be trained to respond to the wearer's own nervous system, and new advances in sensor technology are starting to provide sensory feedback. However, there is still a long way to go before they are able to match the full range and dexterity of human movement and the quality of natural tactile feedback.

But while matching human biology perfectly remains a significant challenge, technology could provide us with the power to make changes that nature never intended. Using modern materials, we could make limbs far stronger than human arms and legs, with a greater range of motion, or with the ability to resist extreme environments.

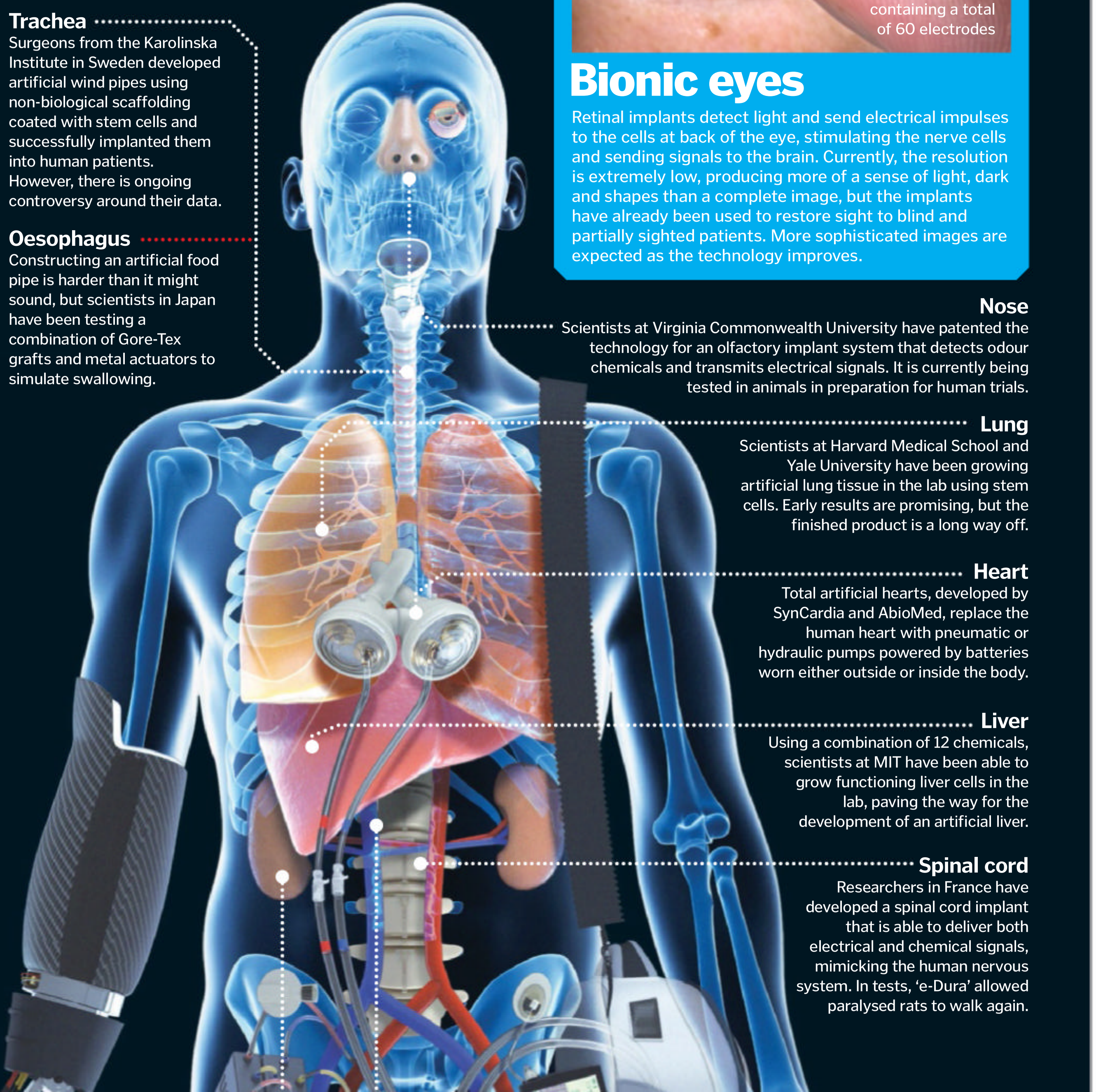
Biology can also be augmented with technology to improve on our natural abilities. In Italy, the Perceptual Robotics Laboratory is developing a wearable robotic exoskeleton called the 'Body Extender'. Using the machine, a strapped-in operator can lift an incredible 50 kilograms (110 pounds) with each arm, and can grip with ten times a human's natural force. And, at the University of Washington, scientists are developing contact lenses containing LEDs that can be activated using radio waves. In the future, this kind of technology could be used to produce a virtual display, conjuring words and images across the front of the eye.

However, the idea of replacing or enhancing healthy human body parts with technological alternatives opens many debates. Most performance-enhancing drugs are already banned in competitive sports because of their potential health risks, and advancements in bionic technologies may pose similar problems. There is also real concern surrounding the ethical issues of augmenting our own biology, particularly in the military, where there might be the potential to create 'super soldiers'.

Looking far into the future, advancements in bionics could ask even more challenging questions. For instance, is there a limit on the number of body parts that can you replace with artificial parts before you are no longer human? And what is it that makes us human in the first place?

Human 2.0

With advances in technology, researchers are preparing humanity for an upgrade



Trachea
Surgeons from the Karolinska Institute in Sweden developed artificial wind pipes using non-biological scaffolding coated with stem cells and successfully implanted them into human patients. However, there is ongoing controversy around their data.

Oesophagus
Constructing an artificial food pipe is harder than it might sound, but scientists in Japan have been testing a combination of Gore-Tex grafts and metal actuators to simulate swallowing.

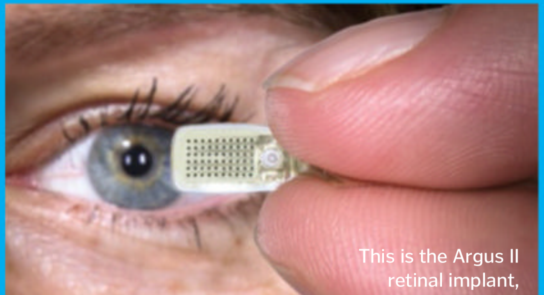
Nose
Scientists at Virginia Commonwealth University have patented the technology for an olfactory implant system that detects odour chemicals and transmits electrical signals. It is currently being tested in animals in preparation for human trials.

Lung
Scientists at Harvard Medical School and Yale University have been growing artificial lung tissue in the lab using stem cells. Early results are promising, but the finished product is a long way off.

Heart
Total artificial hearts, developed by SynCardia and AbioMed, replace the human heart with pneumatic or hydraulic pumps powered by batteries worn either outside or inside the body.

Liver
Using a combination of 12 chemicals, scientists at MIT have been able to grow functioning liver cells in the lab, paving the way for the development of an artificial liver.

Spinal cord
Researchers in France have developed a spinal cord implant that is able to deliver both electrical and chemical signals, mimicking the human nervous system. In tests, 'e-Dura' allowed paralysed rats to walk again.



This is the Argus II retinal implant, containing a total of 60 electrodes

Bionic eyes

Retinal implants detect light and send electrical impulses to the cells at back of the eye, stimulating the nerve cells and sending signals to the brain. Currently, the resolution is extremely low, producing more of a sense of light, dark and shapes than a complete image, but the implants have already been used to restore sight to blind and partially sighted patients. More sophisticated images are expected as the technology improves.

This advanced prosthetic arm was made by DARPA (the Defense Advanced Research Projects Agency), part of the US Department of Defense

Bionic arms

The latest prosthetic arms are packed with technology. Each finger has its own individual motors, and their positions are tracked at all times by microprocessors. Pressure sensors adjust grip automatically when objects start to slip, and movement is controlled by the wearer's own nerves, with the prosthetic picking up tiny electrical signals under the skin in the arm or shoulder, or even nerve signals in the brain.

The latest developments are also giving prosthetics the ability to detect and transmit touch. Scientists at the Case Western Reserve University in Ohio have managed to wire pressure sensors into the nervous system of human patients, allowing them to feel pressure and texture.

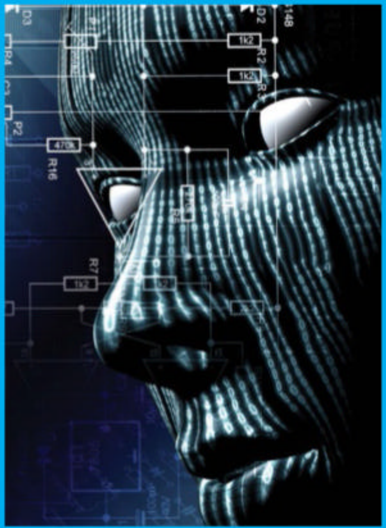
Building brains

The human brain is the most complex structure in the known universe. Replicating it is one of the biggest scientific challenges ever attempted, and different teams are trying different approaches.

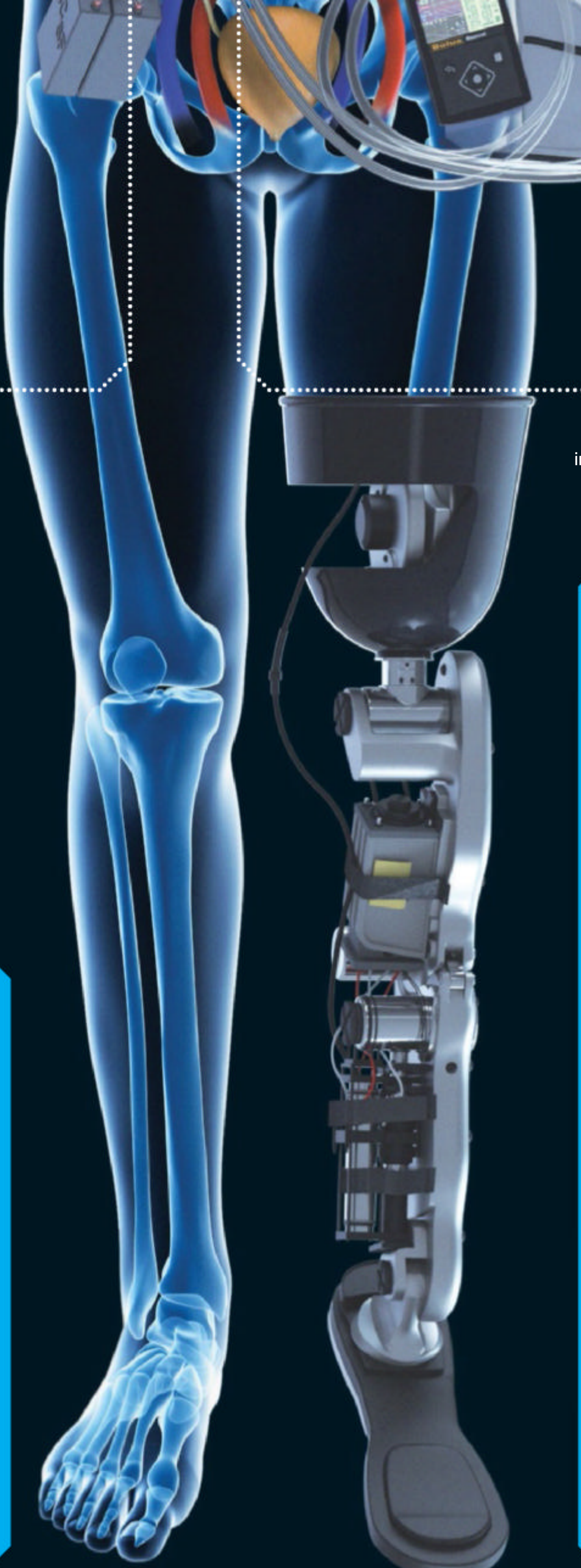
The Blue Brain Project, a collaboration between IBM and Swiss university EPFL, has simulated part of a rat's brain containing 10,000 neurones. By repeating these sections, the team hope to be able to simulate a whole brain.

However, this won't be easy. In 2014, the K computer in Japan managed to simulate one second of activity from one per cent of the human brain. This feat required over 700,000 processor cores and more than 1.4 million gigabytes of RAM, and it still took 40 minutes to complete.

Simplifying the problem is having promising results though. In 2015, the Human Brain Project created a working simulation of a mouse brain by condensing its 75 million neurons to a simplified model of just 200,000 neurons.



The human brain has over 100 trillion connections, known as synapses



Kidneys

Researchers at the University of California, San Francisco are developing an implantable artificial kidney using silicon nanotechnology to filter the blood, and real human kidney cells to reabsorb salt and water.

Pancreas

Researchers at the University of Cambridge have developed an artificial pancreas. A glucose sensor implanted under the skin sends a wireless message telling an insulin pump to deliver the correct dose.

Bionic legs

One of the major hurdles in prosthetic leg design is adjusting between sitting and standing. The majority of older models use switches, but with the addition of robotic sensors, cutting-edge prosthetic legs are now able to intelligently adapt. Not only can they detect movement and weight distribution, but some are also wired in to nerve signals from the thigh muscles, which contain information about the normal position of the ankle.

These sophisticated legs can closely match the capabilities of biological legs, and with a few upgrades, they are even better. For example, changing the shape of the feet can improve climbing ability beyond normal human limits.

Sophisticated prosthetics can stand up to extreme challenges

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Bionic illustration by Nicholas Forder

FORENSIC SCIENCE UNCOVERED

REVEALED: THE INCREDIBLE TECH THAT SOLVES CRIMES AND CONVICTS CRIMINALS

Forensic science has never been under more scrutiny than right now. Since the dissolution of the UK's government-owned Forensic Science Service and the use of private contractors became the norm, every court in the country is on the lookout for mistakes and poor practice; the defence will try to discredit forensic experts to save their clients from prosecution.

The huge popularity of TV shows relating to forensics has not helped either. The general public's expectations have been raised; they expect 100 per cent accuracy and rapid results, both of which are misrepresented in many crime dramas. In some instances, this has led to miscarriages of justice, through the wrongful representation of various theories as undisputed fact. The public struggles to appreciate this; forensic science has long been thought of as a tool to expose wrongful convictions, rather than cause them. The popularity of forensics in the entertainment world has also aided criminals. They now tend to have greater awareness of many of the techniques used by forensic scientists, enabling them to avoid detection with greater success.

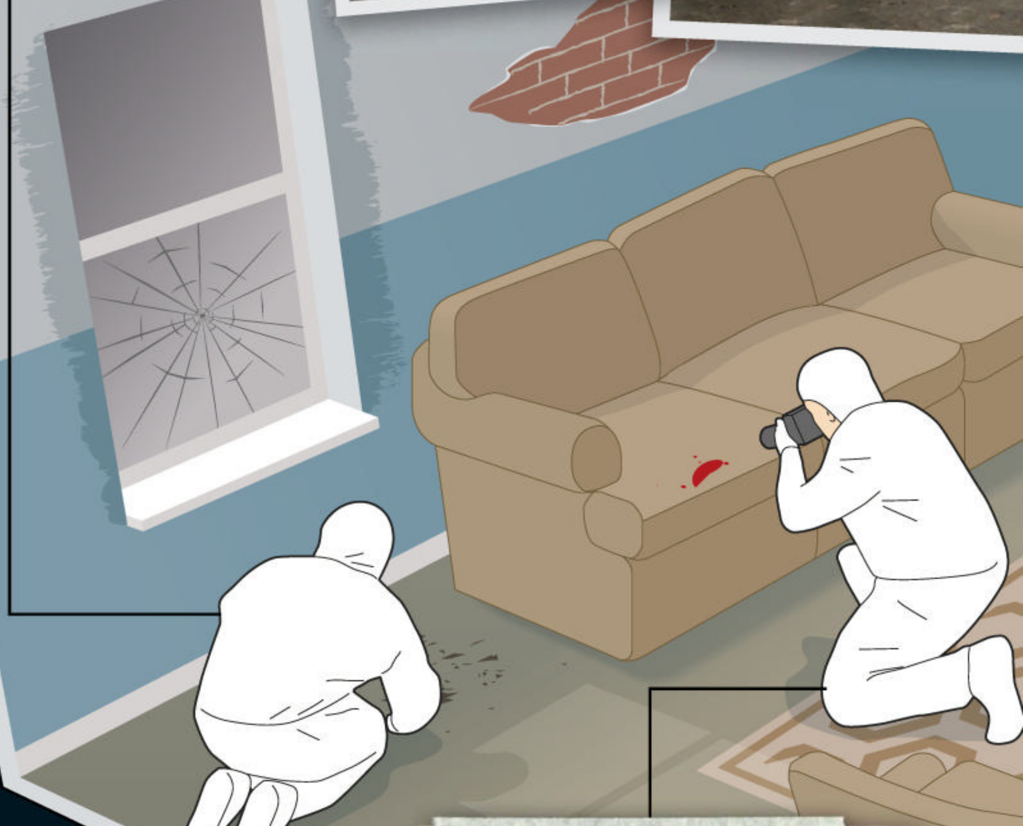
However, the technology used in forensics has developed hugely in the last century. Toxicologists no longer have to taste stomach contents to check for poisons, which was an unsavoury part of their job description during Victorian times. Instead, they can now use precise analytical techniques, such as mass spectrometry and high-performance liquid chromatography, to determine the exact quantity of compounds present in any test sample. DNA technology has breathed life into cases that have been left untouched for decades, and continues to be refined for greater accuracy.

Forensic technology has undeniably improved the police's ability to solve crime, but improvements are still needed. Experts are constantly trying to reduce the length of time analysis takes, as waiting weeks for a DNA result can have a detrimental effect on police investigations, allowing more time for criminals to evade detection. The amount of evidence that needs analysing has created a huge backlog, which means evidence has to be prioritised by what is most likely to reveal probative evidence.

It will be fascinating to see how forensic technology develops over the coming years and whether the new techniques we've featured speed up investigations and lead to convictions.

MATCHING GLASS TO SUSPECTS

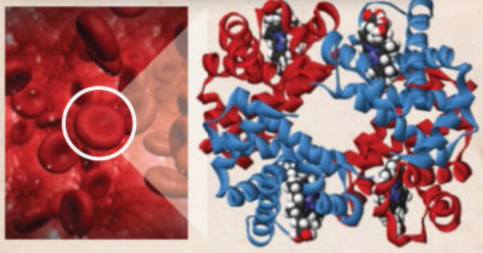
Using a clever type of mass spectrometry involving lasers, it is now possible for even the tiniest fragments of glass to be matched from an individual to crime-scene samples.



DATING BLOOD SAMPLES

A revolutionary camera that can scan the visible spectrum of haemoglobin could make it possible to date blood stains to within a day, potentially even within an hour. This hyperspectral imaging device could enable police to immediately establish time of death, which currently takes days to achieve. It's thought that this technology could be adapted to confirm the presence of other fluids, such as saliva and sweat.

HAEMOGLOBIN

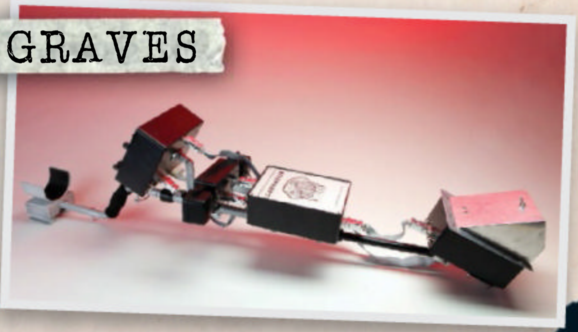


Haemoglobin is a protein made up of four polypeptide chains, each joined to an iron-containing haeme group

DID YOU KNOW? *The roots of hairs can be used to determine gender, as they contain DNA*

SNIFFING OUT HIDDEN GRAVES

Locating hidden graves is both timely and costly, impacting law enforcement and military operations globally. The lightweight analyser for buried remains and decomposition odour recognition device – LABRADOR for short – claims to help find hidden graves. As our bodies decay, over 400 chemicals are released, producing a unique chemical signature that this device identifies. Its potential applications are vast, and include detecting narcotics, accelerants and even explosives.

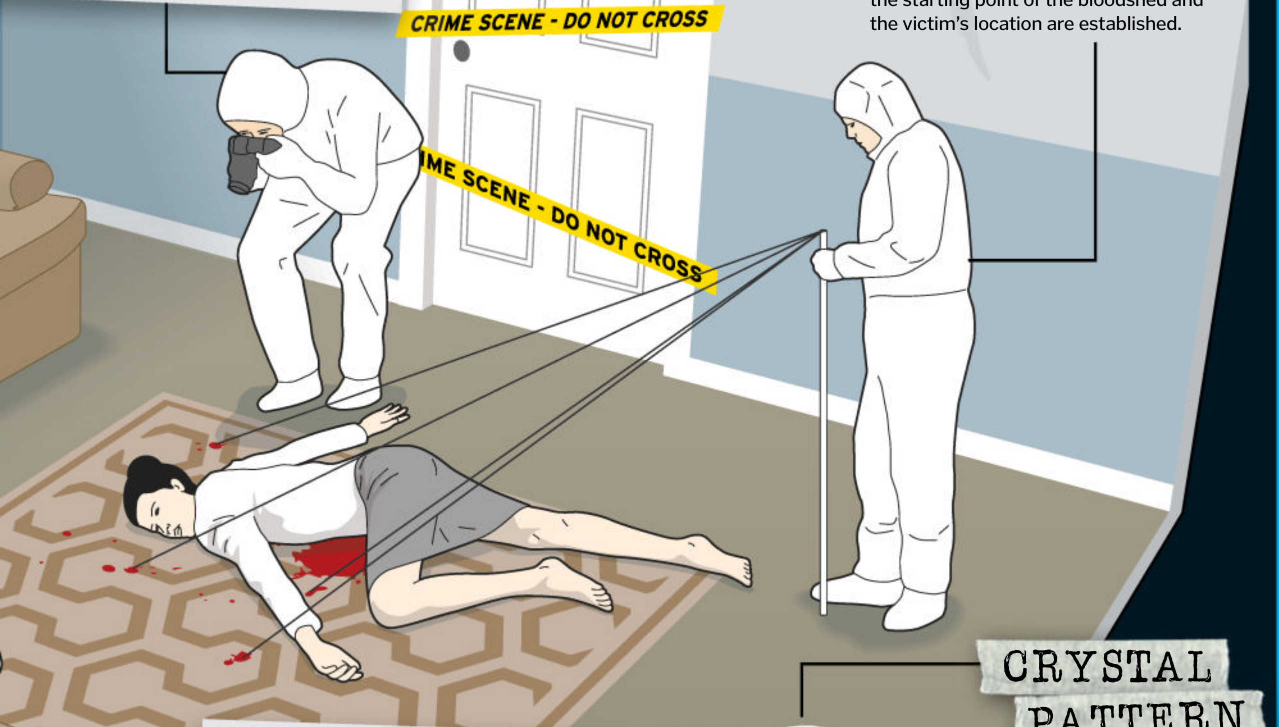


CRIME-SCENE PHOTOGRAPHY

When photographing a crime scene, it is imperative the photographer does not delete a single image, as this would be deemed as tampering with evidence.

AREA OF CONVERGENCE

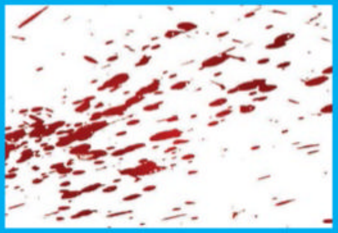
When bloodstain pattern analysts arrive at a crime scene, they will examine the distribution, size, shape and location of the bloodstains, to determine what has happened. Using the stringing method, the analyst will record the location of each spatter by employing the coordinate system. By determining both the angle and direction of each spatter, the starting point of the bloodshed and the victim's location are established.


CRIME SCENE - DO NOT CROSS
CRIME SCENE - DO NOT CROSS
ME SCENE - DO NOT CROSS

CRYSTAL PATTERN MAPPING

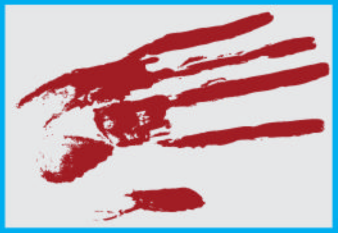
In order to make the identification of stolen goods harder, criminals will remove any form of serial number. By using electron backscatter diffraction (EBSD), it is possible to map the deformations in the metal's crystal structure, revealing the removed information. This technique could prove useful for reconstructing vehicle identification numbers, or even the imprints left on ammunition casings.

Blood pattern analysis

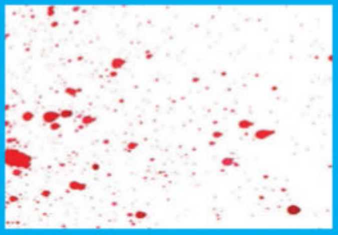


Cast-off
Cast-off stains are often formed when a bloodied weapon is swung through the air, casting blood onto a nearby surface.

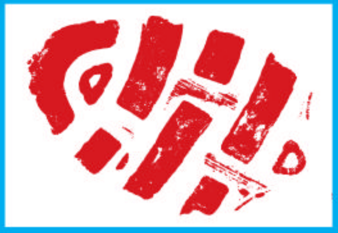
Shadowing or ghosting
A gap in an otherwise consistent spatter typically indicates that an object was present at the time of the incident.



Swipes and wipes
Wipes are seen when blood on a surface is smeared, whereas swipes occur when an object covered in blood brushes a separate surface.



Expiratory blood
Blood exhaled by a person creates a unique pattern. This is typically misty, somewhat resembling high-velocity spatter.



Transfer
Transfer patterns form when a bloody object is pressed against a clean surface. This is often seen with bloody footprints.

© CCTextures; Thinkstock; OJO Images/REX

VIRTUAL AUTOPSY

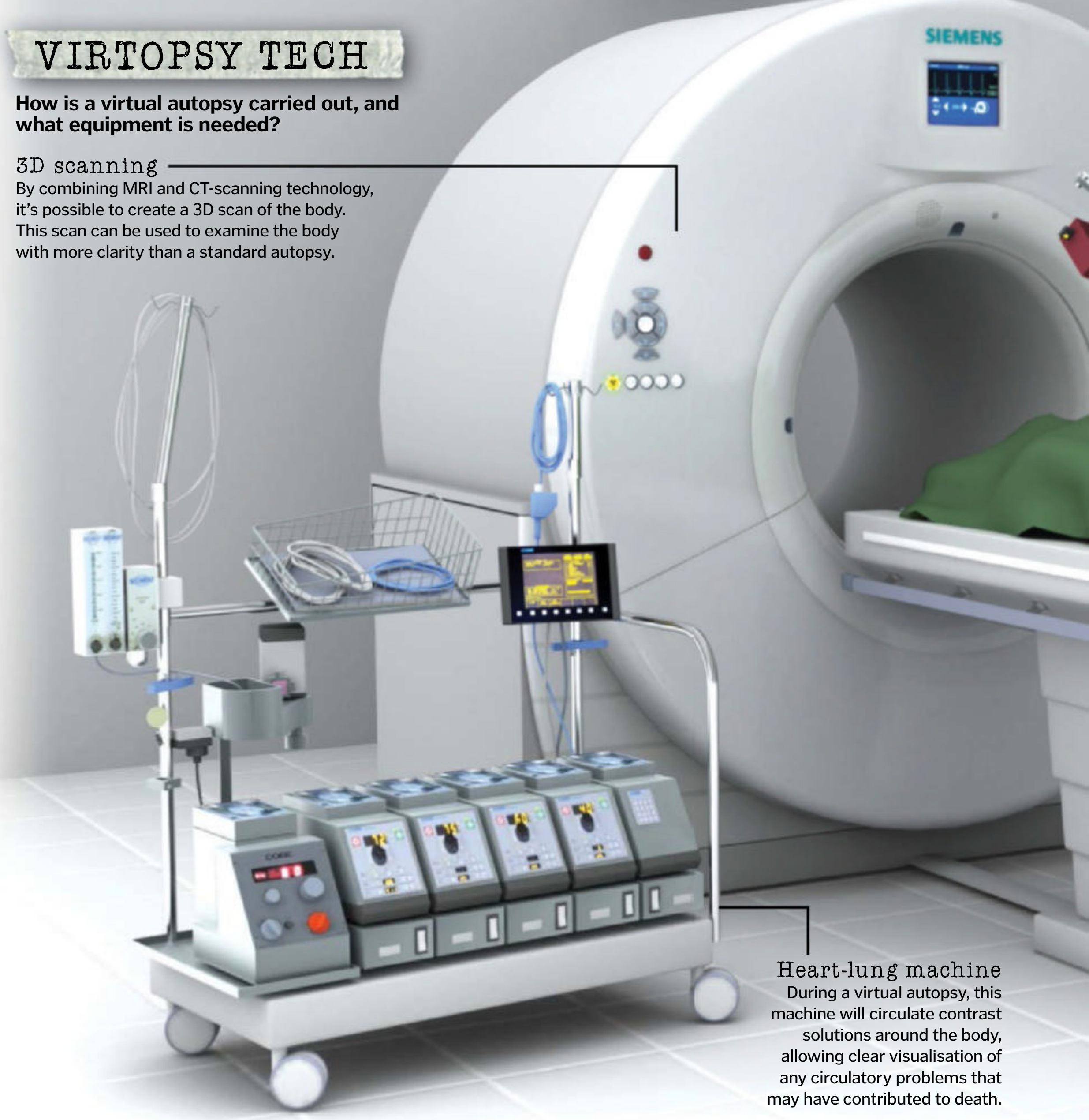
CAN CAUSE OF DEATH BE ESTABLISHED WITHOUT DISSECTING A CORPSE?

Autopsies are a messy business in more ways than one. They can take hours to perform, and further analytical results can take months to produce. This not only delays forensic investigation; it can also add to the grief the deceased person's relatives experience. On top of this, researchers believe more than ten per cent of post-mortems are not completed to a satisfactory standard, meaning many suspicious deaths are never correctly identified.

The new virtual autopsy, or 'virtopsy', aims to speed up the entire process and achieve faster results. They offer the advantage of preserving a virtual form of the body, which can be continually reviewed and analysed. This will greatly increase accuracy, as multiple experts will be able to simultaneously examine the corpse, which is impossible to do during traditional post-mortems. The ability to gather nondestructive findings is a huge benefit of a 'virtopsy'; many families would rather their loved ones' bodies weren't subjected to the rigours of a traditional post-mortem. By using the virtopsy software, precise areas of interest can be chosen for further investigation, allowing pathologists to reduce the time they spend physically looking for clues in the body. Although unlikely to completely replace the traditional autopsy, the virtopsy has huge potential to speed up the process and greatly reduce the chance of missing vital evidence.

VIRTOPSY TECH

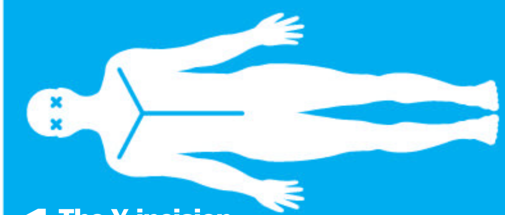
How is a virtual autopsy carried out, and what equipment is needed?

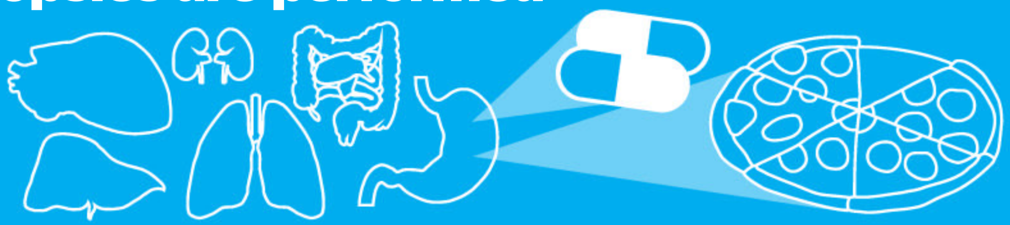


3D scanning
By combining MRI and CT-scanning technology, it's possible to create a 3D scan of the body. This scan can be used to examine the body with more clarity than a standard autopsy.

Heart-lung machine
During a virtual autopsy, this machine will circulate contrast solutions around the body, allowing clear visualisation of any circulatory problems that may have contributed to death.

How traditional autopsies are performed



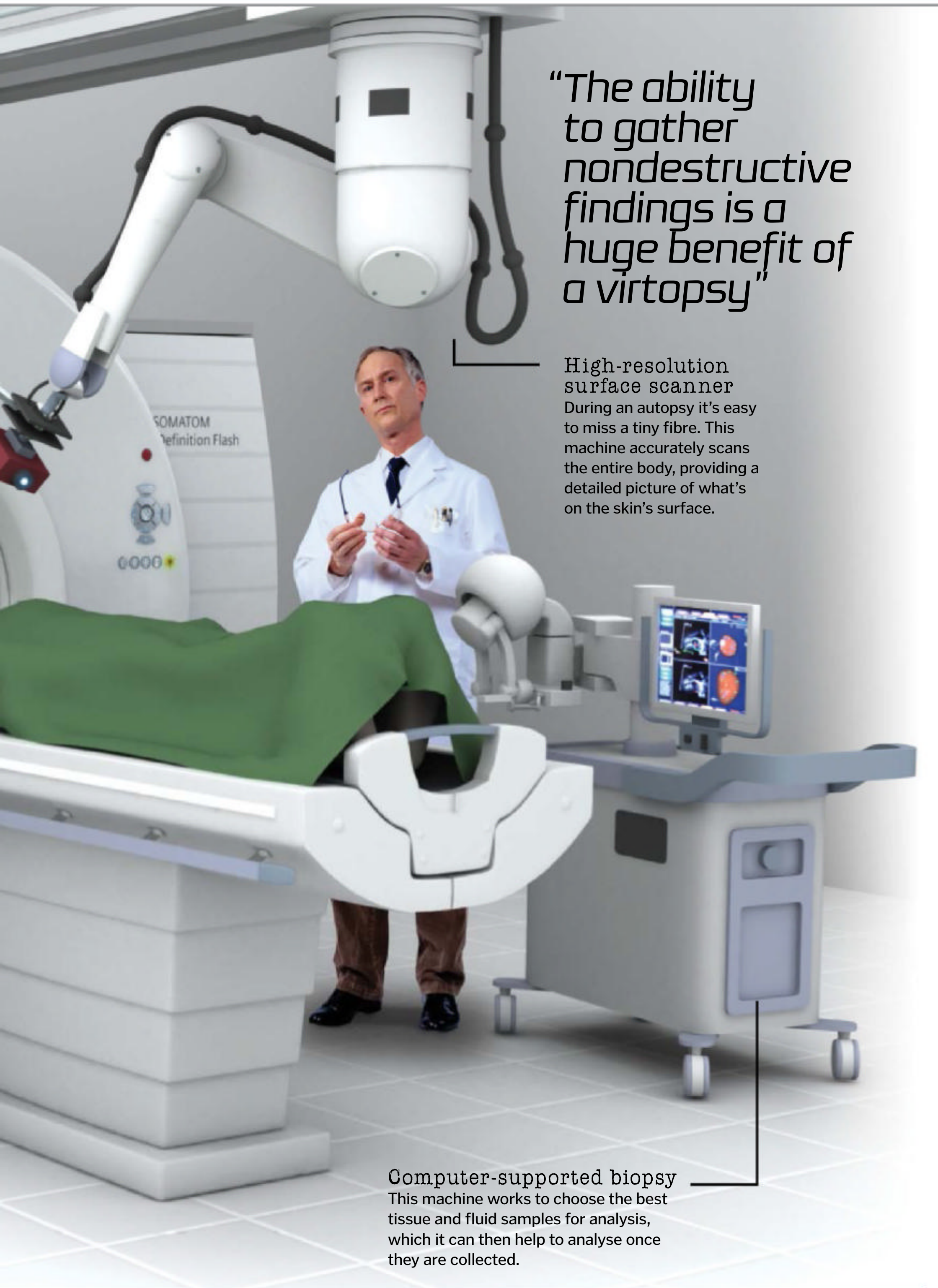


1 The Y-incision
The pathologist will perform a Y-shaped incision by cutting from each shoulder to the sternum, then down to the abdomen. This allows access to the major organs.

2 Organ removal
All of the body's major organs are removed and weighed for comparison. Blood and DNA samples are obtained and the heart is examined for signs of poisoning.

3 Stomach contents
The stomach contents reveal the deceased's last meal. Time of death can also be calculated by analysing the amount of digestion that has taken place.

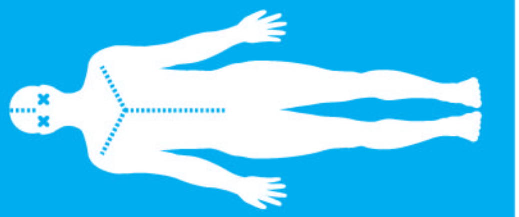
DID YOU KNOW? *Red blood cells do not possess a cell nucleus, making them a poor source of DNA*



> *"The ability to gather nondestructive findings is a huge benefit of a virtopsy"*

High-resolution surface scanner
During an autopsy it's easy to miss a tiny fibre. This machine accurately scans the entire body, providing a detailed picture of what's on the skin's surface.

Computer-supported biopsy
This machine works to choose the best tissue and fluid samples for analysis, which it can then help to analyse once they are collected.



4 Brain examination
The brain is thoroughly examined for signs of injury or abnormality. Often it will be preserved in formalin, which will harden the brain, allowing it to be dissected with greater accuracy.

5 Replacement
After all of the previous procedures have been conducted, the organs will be placed back inside the body cavity and the Y-incision will be sewed up. Samples may be further analysed.

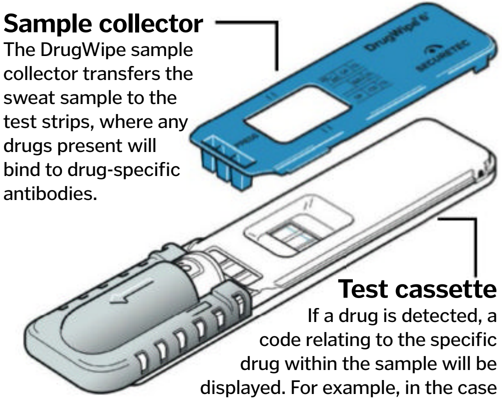
Roadside drug testing

Drugs have the ability to slow reactions, increase risk taking and alter judgement, all of which are detrimental to a person's ability to drive safely. It's important to remember that not only illegal drugs cause problems; people on prescription medication can be just as dangerous if they fail to follow their doctor's guidance.

Drug driving is a frequent problem across the globe. Due to the overall lack of a definitive roadside test for drugs, many users believe they can get away with driving under the influence and tend to be more worried about being caught in possession. The UK and US have relied heavily on a set of impairment tests to detect drug intoxication, but these are unreliable and don't tell you the identity of the ingested drug.

The Securetec DrugWipe can detect up to five substances, including cocaine and cannabis, in a single test using a person's sweat. Results are available after three to ten minutes, making it feasible for police to use the device at the roadside. By using highly specific antibodies, it is able to guarantee reliable drug detection.

A range of other forms of DrugWipe are available depending on what you want to test for. This includes a test for ketamine, which is currently the fourth most popular recreational drug in the UK. Using sweat is a more reliable test of impairment compared to many oral tests. This is because drug deposits can form in the mouth, providing a positive test even though the drug may have been taken days before, meaning the individual would not be impaired at the time of testing.



Sample collector
The DrugWipe sample collector transfers the sweat sample to the test strips, where any drugs present will bind to drug-specific antibodies.

Test cassette
If a drug is detected, a code relating to the specific drug within the sample will be displayed. For example, in the case of cannabis, "CA" would be shown.

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FORENSIC HOLODECK RECREATES CRIMES IN 3D

NEW VR TECH WILL HELP JURY MEMBERS VISUALISE CRIME SCENES

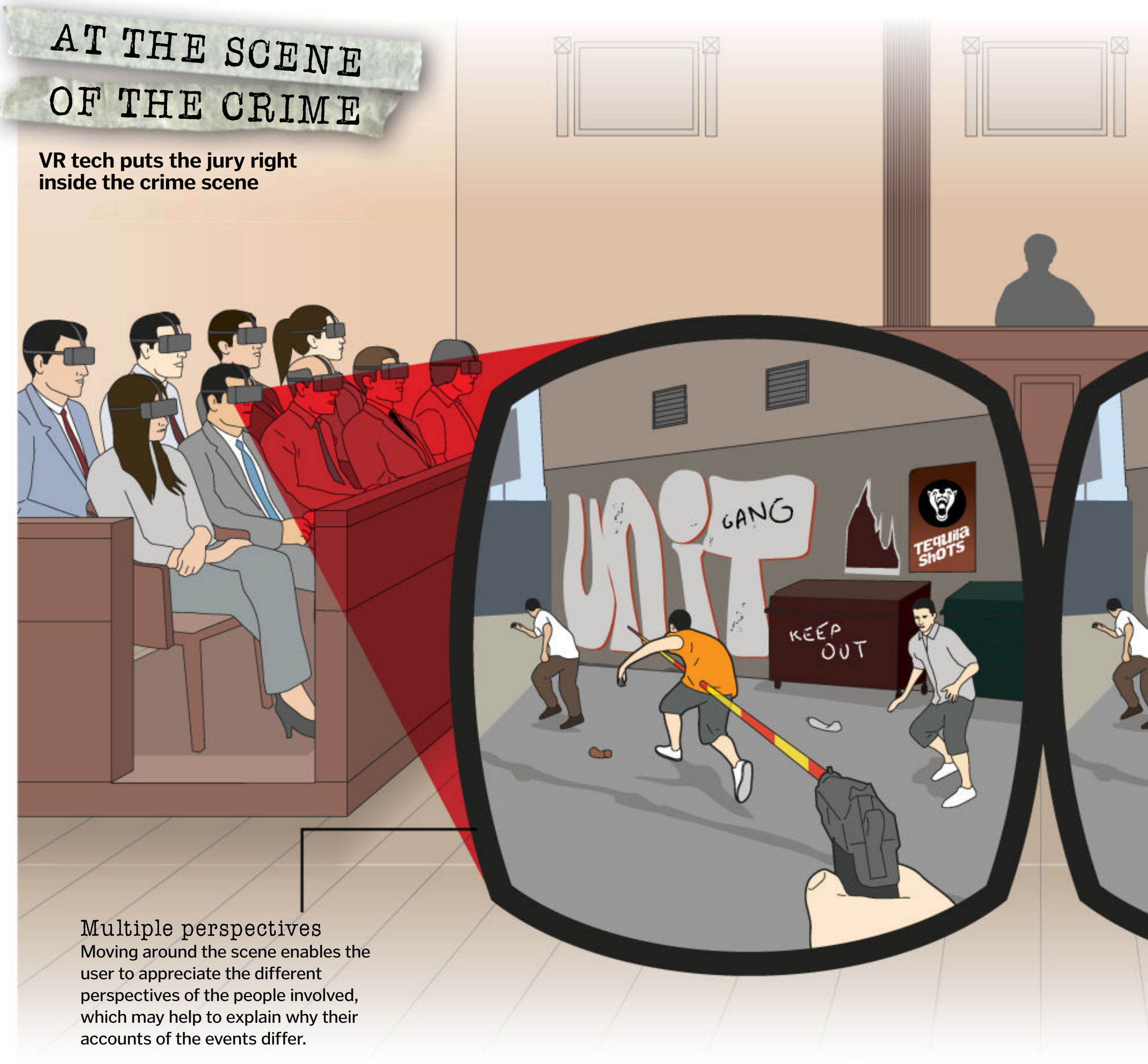
Reconstructing a crime scene is one of the toughest jobs for any forensic scientist. This is particularly apparent when they give evidence in court. It's vital that both the judge and jury are able to develop detailed knowledge of any crime scene, in order to figure out what happened as well as the precise order of events. Without live footage of the scene, this has been incredibly difficult to achieve; photos of the scene and other types of evidence presented to the jury often leave much to the imagination.

By combining MRI, CT, laser-scanning technology, camera footage, eyewitness statements and the virtual reality headset, Oculus Rift, the forensic holodeck has been created. Using this new technology, all members of a courtroom may soon be able to walk through the crime scene in high-resolution 3D. Named after the simulated-reality device featured in *Star Trek*, an advantage of the forensic holodeck is that it can simplify a scene. This can help show exactly the evidence in question, or make particularly violent scenes less traumatic for the jury. Being able to appreciate a particular individual's line of sight is another significant benefit, as this can show whether someone is telling the truth about what they saw, or whether a suspect could be seen by certain individuals.

The Oculus Rift is able to measure the user's orientation in real-time, which allows crime scenes to be viewed with the correct perspective. Originally designed for use in the world of videogames, the Oculus Rift has been modified so that it can measure the user's position with the help of an optical tracker.

AT THE SCENE OF THE CRIME

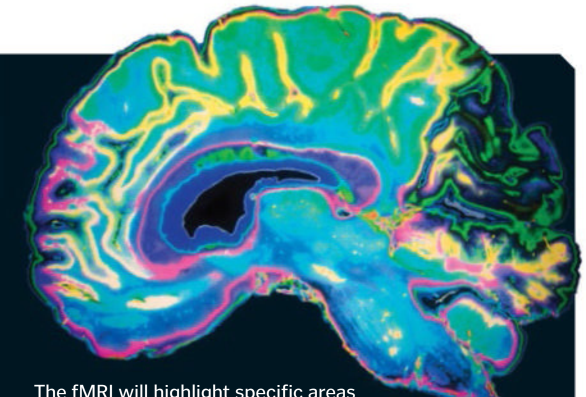
VR tech puts the jury right inside the crime scene



Multiple perspectives
Moving around the scene enables the user to appreciate the different perspectives of the people involved, which may help to explain why their accounts of the events differ.

How lies can be 'seen' in the brain

Researchers claim to have found the gold standard in lie detection, by monitoring the brain with functional magnetic resonance imaging (fMRI). Research has shown that telling lies increases blood flow to the brain, which in turn increases oxygen levels. This increased oxygen level causes the brain to brighten in the fMRI image. Scientists believe this method is much harder to cheat than a traditional polygraph, as the fMRI continually tracks changes in the brain. Polygraphs only measure typical stress responses and link them to the chance of a subject answering untruthfully.

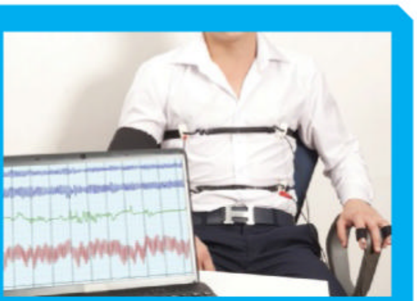


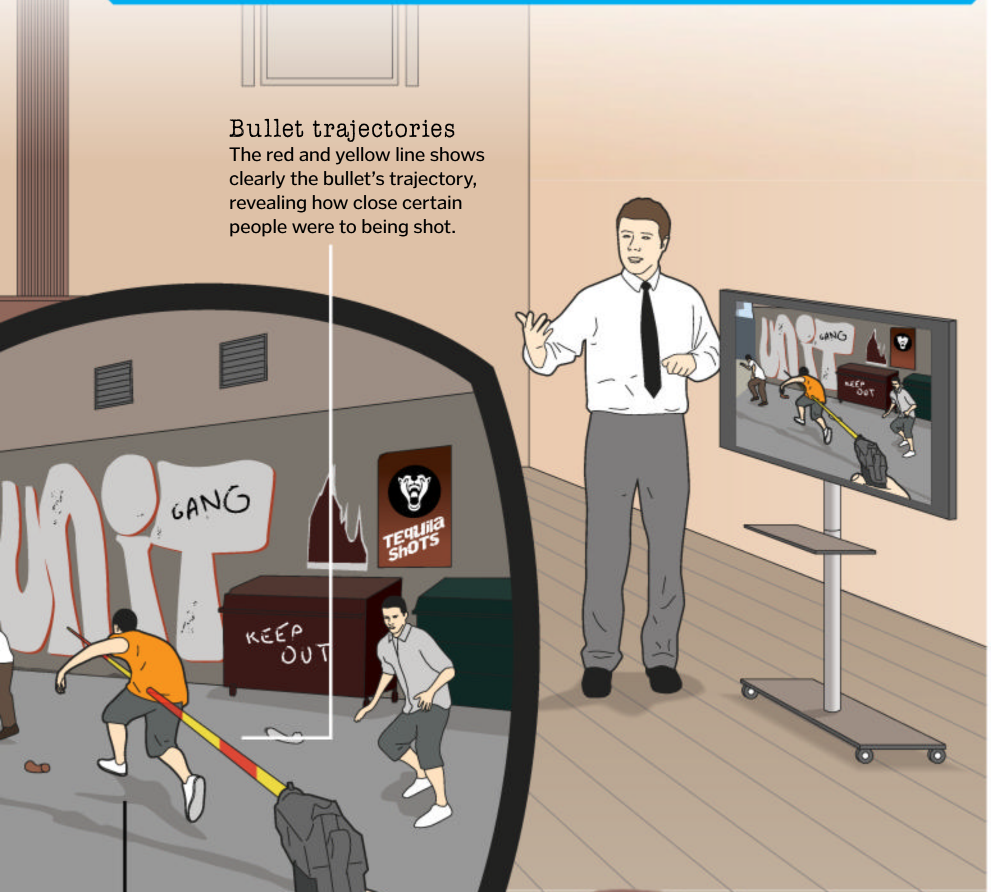
The fMRI will highlight specific areas in the brain to show increased blood flow

DID YOU KNOW? *Bite-mark analysis was used in 1954 to convict a burglar who bit on a piece of cheese during a robbery*

Polygraphs debunked

Polygraphs detect lies by measuring physiological changes, such as blood pressure and sweating. The key to beating them is to answer the control changes strangely. Your control answers are what the polygraph bases your test answers on, therefore by changing your blood pressure, respiratory rate and sweat levels when telling the truth, the polygraph won't be able to detect lies during the test.


Polygraph tests aren't standardised and therefore they lack scientific validity



Bullet trajectories
The red and yellow line shows clearly the bullet's trajectory, revealing how close certain people were to being shot.

Victim location
By moving around the scene, it's possible to appreciate the exact locations of the various suspects, victims and witnesses.

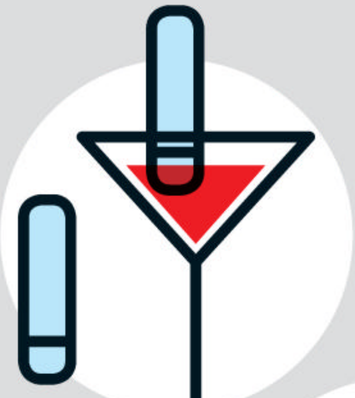
"Telling lies increases blood flow to the brain"

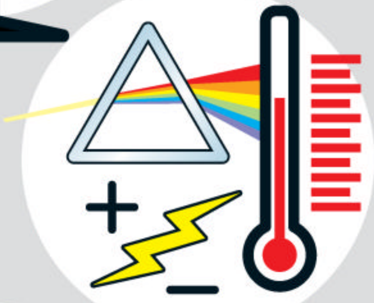
DIY spiking test

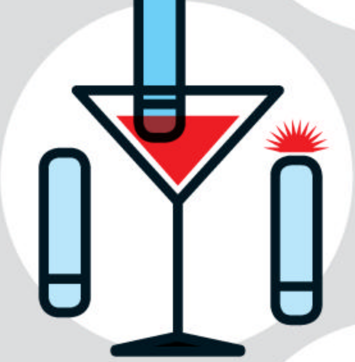
How to perform your own forensic analysis to see if your drink has been spiked

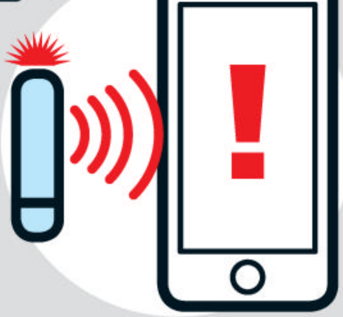
Proving someone has had their drink spiked is notoriously hard to do. For many years, claims of being spiked have been met with scepticism, and any symptoms reported by the individual put down to alcohol intoxication. The problem lies in the fact that very little evidence is ever preserved; the drug is often completely metabolised by the time the victim reports the crime and the glass has usually been cleaned or lost.

Similar in shape and size to a USB stick, the Personal Drink Identification Device, or pd.id, aims to let users test their own drink to see whether it contains a common date-rape drug. Operated simply by dipping it into a drink, it can identify whether your drink has been modified in some way, by examining the drink's components. It then compares them to a preloaded database of known substances and drink characteristics, to see whether or not there are any anomalies present in the drink.


Once the pd.id is submerged in the drink, it collects a small sample of liquid in a reservoir.


By performing three tests involving light, current and temperature, the drink's components are analysed.


The analysis takes only a few seconds; once it's complete the LED light will indicate whether the drink is safe to consume.


By linking with your smartphone, the pd.id can access a larger database of drink profiles, and can text or call you if your drink is contaminated.

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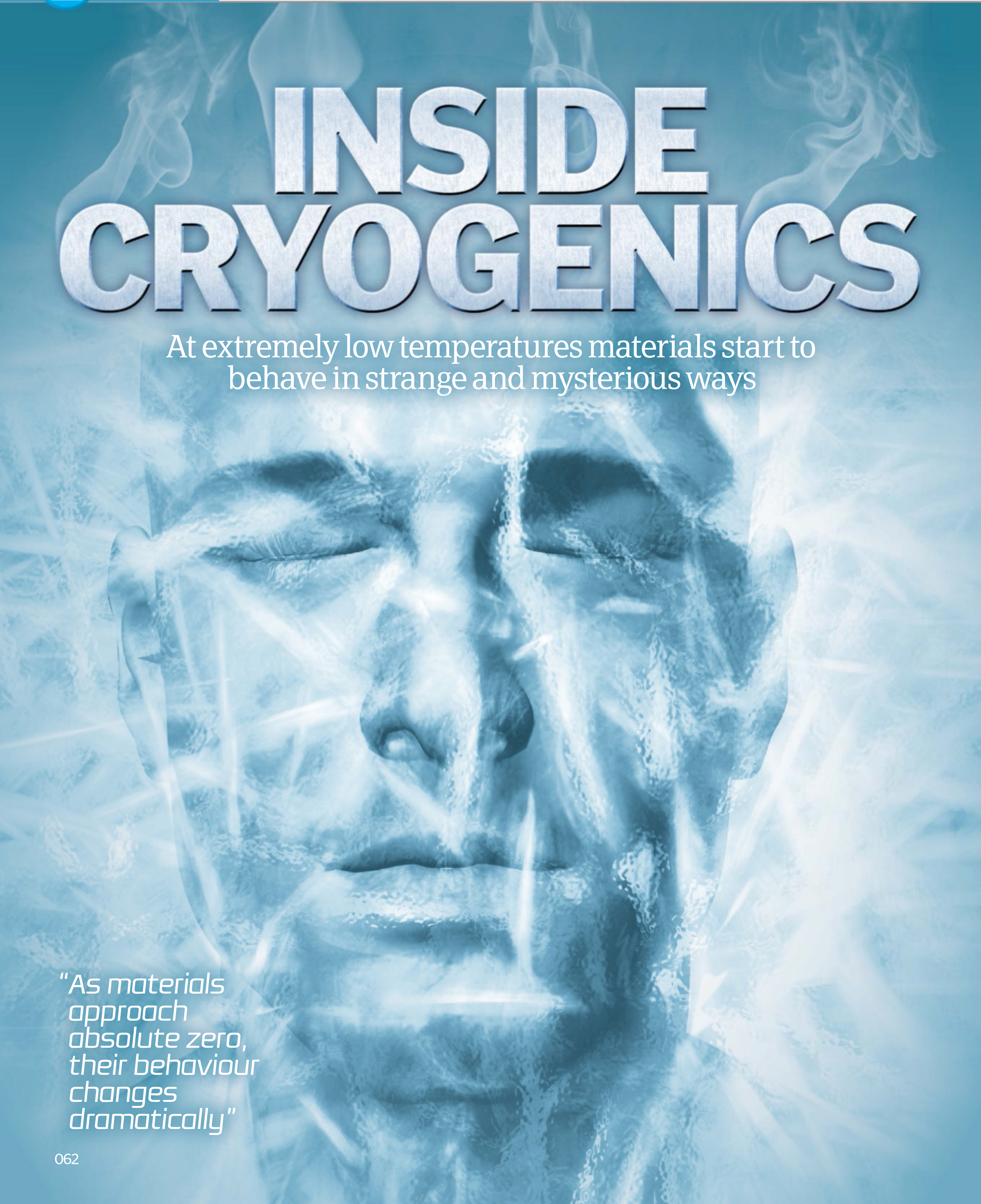
INSIDE CRYOGENICS

At extremely low temperatures materials start to behave in strange and mysterious ways



> "As materials approach absolute zero, their behaviour changes dramatically"

DID YOU KNOW? *Liquid nitrogen is used by chefs to rapidly freeze ice cream, giving the dessert an unusually smooth texture*

ICY DEAD PEOPLE

Cryogenics versus cryonics

When people talk about cryogenics, one of the first things that comes to mind is frozen bodies waiting patiently in tanks for future reanimation. This idea was popularised by science fiction, and is performed in specialist facilities in the United States, but the scientific evidence is severely lacking.

Scientists are careful to separate the real science of cryogenics from the practice of freezing human bodies, and the field has its own name – cryonics. After a cryonics patient is pronounced dead, their blood is removed and replaced with a cocktail of chemicals that aim to protect the delicate cells from the freezing process.

Once this procedure is complete, the body is frozen using liquid nitrogen and stored in a holding tank. There is no requirement for cryonics companies to be scientifically or medically certified, and some of the work is carried out by volunteers. Despite the undeniably exciting concept, there is still no evidence that whole-body freezing procedures are effective.

Cryonics is the practice of freezing human remains in the hope that one day they might be brought back to life

Cryogenics is the science of extreme cold. Research in this field aims to understand how to produce and maintain temperatures below 123 degrees Kelvin, or minus-150 degrees Celsius (minus-238 degrees Fahrenheit), and to study the effects of these freezing environments on various different physical, chemical and biological processes.

Heat is generated by the random movement of molecules, and as the temperature drops they start to slow down. According to the laws of thermodynamics this cannot continue indefinitely – there must be a bottom, a point at which molecular motion stops completely. This point, the coldest possible temperature, is known as absolute zero, or zero degrees Kelvin (minus-273.15 degrees Celsius / minus-459.67 degrees Fahrenheit).

As materials' temperature approaches absolute zero, their behaviour changes dramatically. When permanent gases such as nitrogen and oxygen reach temperatures in the tens of Kelvins, they can be turned into liquids, which can be used as fuel for spacecraft, to rapidly cool food for preservation, or even for the surgical removal of damaged cells in the body.

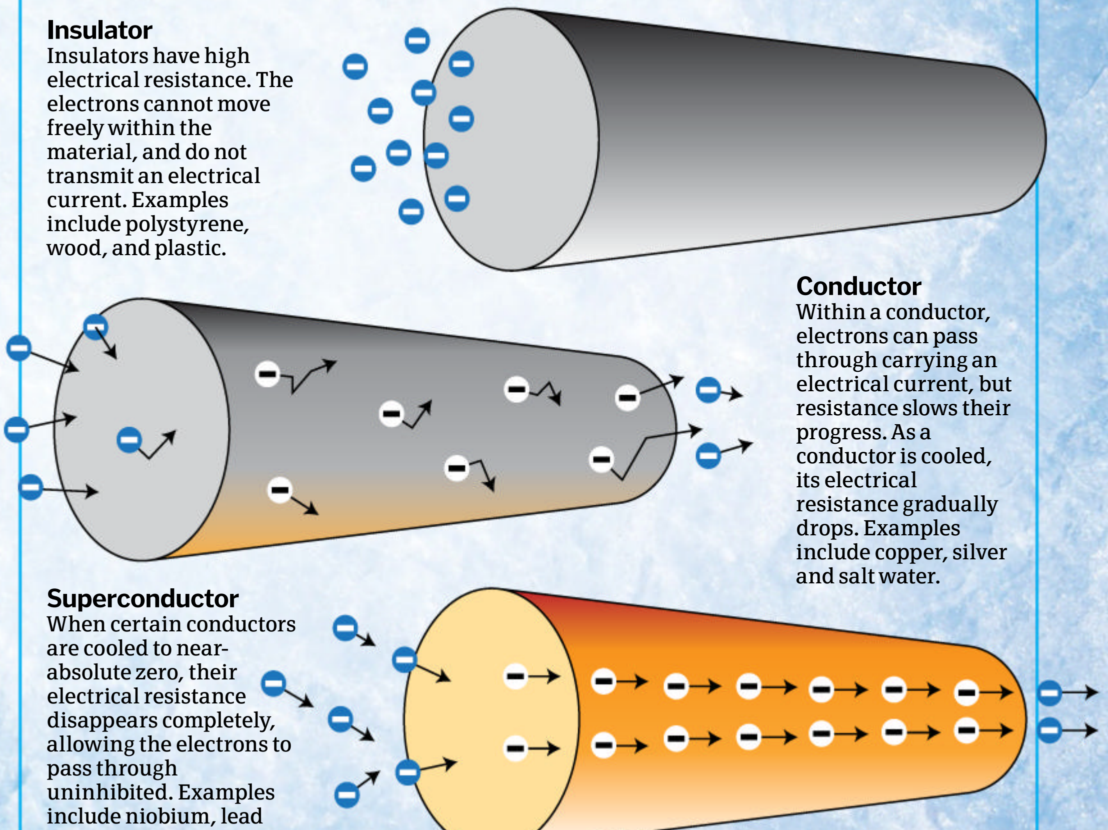
When niobium alloys drop close to absolute zero, they completely lose their electrical resistance, and subsequently become superconductors, capable of producing powerful electromagnets that can accelerate subatomic particles to almost the speed of light. And when the temperature reaches 2.19 degrees Kelvin or lower, helium loses its viscosity and becomes a superfluid that can, amazingly enough, crawl up the sides of glass beakers. It's a pretty crazy sight.

Join us as we investigate some of the ways cryogenics is pushing the frontiers of science as we know it.

KEEPING CERN COOL WITH CRYOELECTRONICS

The flow of electrical current through a conductor is opposed by material resistance, but as the temperature of certain metals falls, this resistance drops away. In some cases, at these super-low cryogenic temperatures, electrical resistance suddenly drops to zero, creating a superconductor.

The main magnets that guide particle beams around the Large Hadron Collider at CERN are cooled with liquid helium to a temperature of 1.9 degrees Kelvin (-271.3 degrees Celsius / -456.3 degrees Fahrenheit) – that's colder than in outer space. Their resistance completely disappears, preventing energy being lost as heat.



Insulator
Insulators have high electrical resistance. The electrons cannot move freely within the material, and do not transmit an electrical current. Examples include polystyrene, wood, and plastic.

Conductor
Within a conductor, electrons can pass through carrying an electrical current, but resistance slows their progress. As a conductor is cooled, its electrical resistance gradually drops. Examples include copper, silver and salt water.

Superconductor
When certain conductors are cooled to near-absolute zero, their electrical resistance disappears completely, allowing the electrons to pass through uninhibited. Examples include niobium, lead and mercury.

The core stage of NASA's new Space Launch System (SLS) will be powered by four RS-25 liquid-fuel engines

Fuelling rockets

One of the major applications of cryogenics is in space travel; the first cryogenically fuelled rocket was NASA's Centaur upper stage, first successfully launched in 1963.

The most commonly used cryogenic pairing is liquid hydrogen fuel (LH_2), burnt using liquid oxygen (LO_2 or LOX). Hydrogen is a light gas that burns cleanly in the presence of oxygen, and by cooling both gases to extremely low temperatures, more fuel can be crammed into each tank.

The tanks are exposed to a number of different heat sources during space flight, from the engine's exhaust to friction as the craft travels through the atmosphere, and the heat from the Sun. To keep the fuels liquid, the tanks must not only be well insulated, but also able to withstand the extremely low temperatures of the cryogenic fluids inside.

The fuels are traditionally contained in heavy metal tanks, but NASA and Boeing are working on a revolutionary composite fuel tank, 30 per cent lighter than standard cryogenic tanks. In the future, these tanks will allow more fuel to be carried, taking cargo farther into space than ever before.

MAKING METALS STRONGER

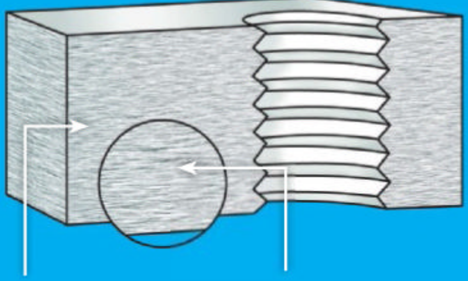
As metal cools from a liquid to a solid, it forms a crystal structure, with the individual atoms arranged into a regular lattice, but there are often imperfections to this. Traditionally, these are minimised using heat treatment, allowing the metal to become liquid again to relieve stress and fill in the gaps, but the process is incomplete. Using cryogenic technology, the imperfections and stresses in heat-treated metal can be removed.

Following heat treatment, the metal is slowly cooled to near-absolute zero. The process allows certain elements within the structure to move, filling in the microscopic defects and making the structure more uniform. This relieves stress and results in a denser, more resilient metal. Cold-treated metals are used in sport to create golf clubs and baseball bats with less vibration, so more energy can be transferred to the balls.

BEFORE

Heat-treated steel

Steel is traditionally heat-treated to improve its strength. At high temperatures, the imperfect internal structure melts and can reform evenly.



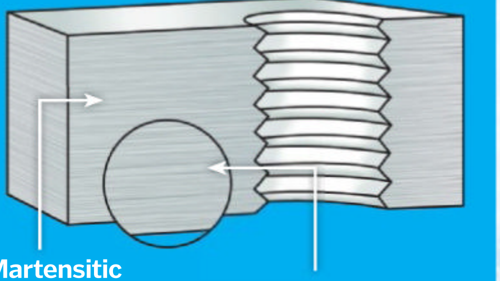
Quenching
Heat-treated steel is cooled slowly, allowing 60-80 per cent of the molecules to settle into a tight, regular structure.

Stress
The cooling process introduces stresses as the outside contracts before the red-hot centre has had time to cool.

AFTER

Cryogenic treatment

After heat-treating, the temperature of the metal is gradually lowered toward absolute zero.



Martensitic structure
As the metal cools and contracts, the structure is forced into line, transforming into a uniform structure.

Stress relief
Cryogenic treatment allows the molecules within the metal to redistribute gradually, relieving stresses introduced by heat treatment.

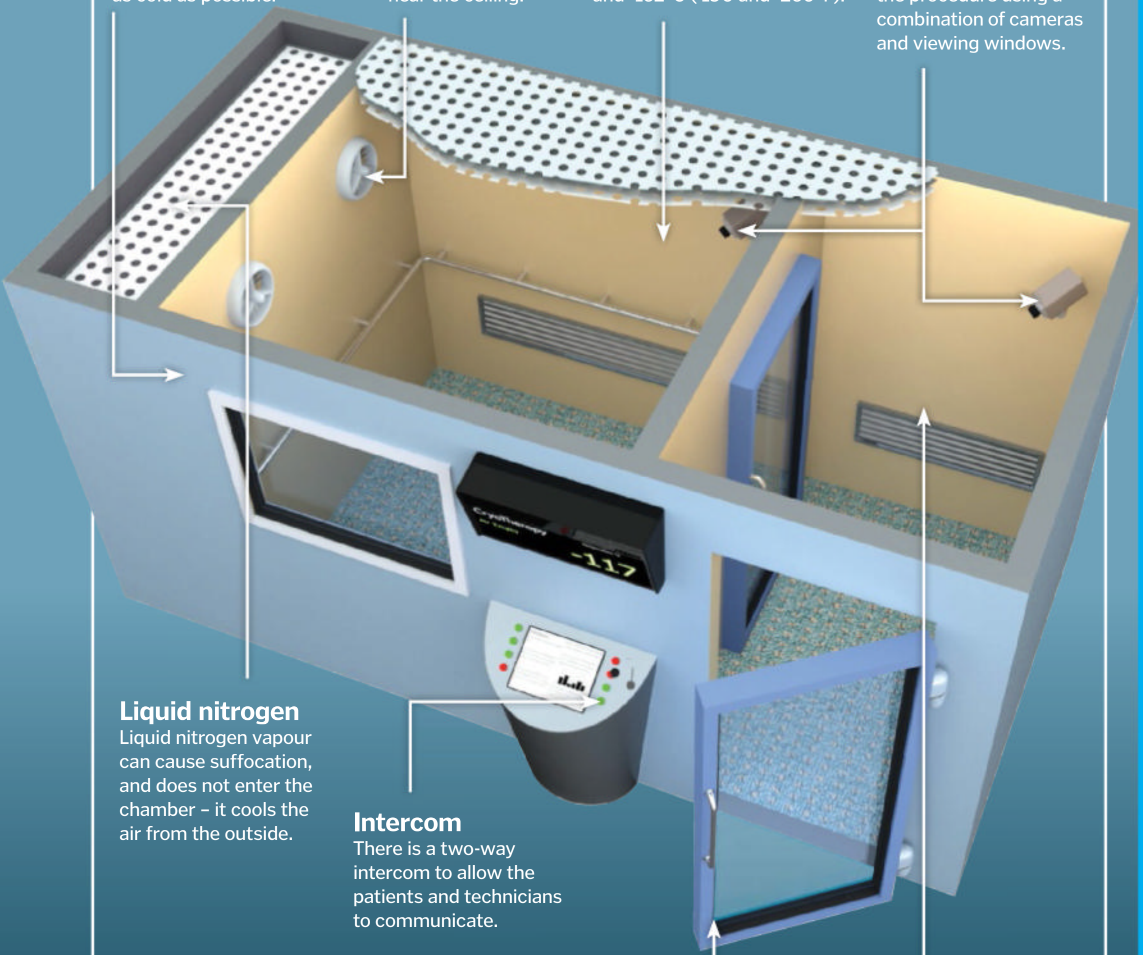
TREATING SPORTS INJURIES

Not all cryogenic techniques are well established, and in the sporting world, there is an emerging field in whole-body cryotherapy (WBC). Traditionally, ice and cold-water immersion have been used to treat sports injuries, but this new approach, based on research originally pioneered in Japan in the 1970s, aims to relieve the symptoms of athletic injury, muscle and joint pain, and arthritis by cooling the entire body in a cryogenic chamber. Air is a poor conductor compared to water, so there is a much lower chance of the core body temperature being affected than with traditional techniques.

Entering the nitrogen-cooled chamber, people are exposed to temperatures lower than minus-100 degrees Celsius (minus-148 degrees Fahrenheit) for a period of around three minutes. Their extremities are protected with clothing, gloves, socks, facemasks and underwear, but other than that, their skin is exposed to extreme temperatures. The body's natural response is to cut off the blood supply to the skin, redirecting it to the core in order to minimise heat loss and maintain a healthy internal body temperature. A by-product of this is the release of natural painkillers known as endorphins, which can induce feelings of well-being and euphoria.

ENTERING THE CRYOCHAMBER

Patients spend up to three minutes in these superchilled rooms



Insulated walls
The walls of the chamber are insulated to ensure the temperature inside remains as cold as possible.

Air diffuser
Normal air enters the chamber through vents near the ceiling.

Main chamber
The air in the main treatment chamber is maintained at temperatures between -123 and -162°C (-190 and -260°F).

Monitoring cameras
The patients are monitored throughout the procedure using a combination of cameras and viewing windows.

Liquid nitrogen
Liquid nitrogen vapour can cause suffocation, and does not enter the chamber – it cools the air from the outside.

Intercom
There is a two-way intercom to allow the patients and technicians to communicate.

Magnetic doors
The doors are closed using magnets, allowing the patients to leave easily if they need to.

Pre-chamber
Patients acclimatise to the cold in the first chamber, kept at a slightly warmer -40 to -62°C (-40 to -80°F).

Treating arthritis

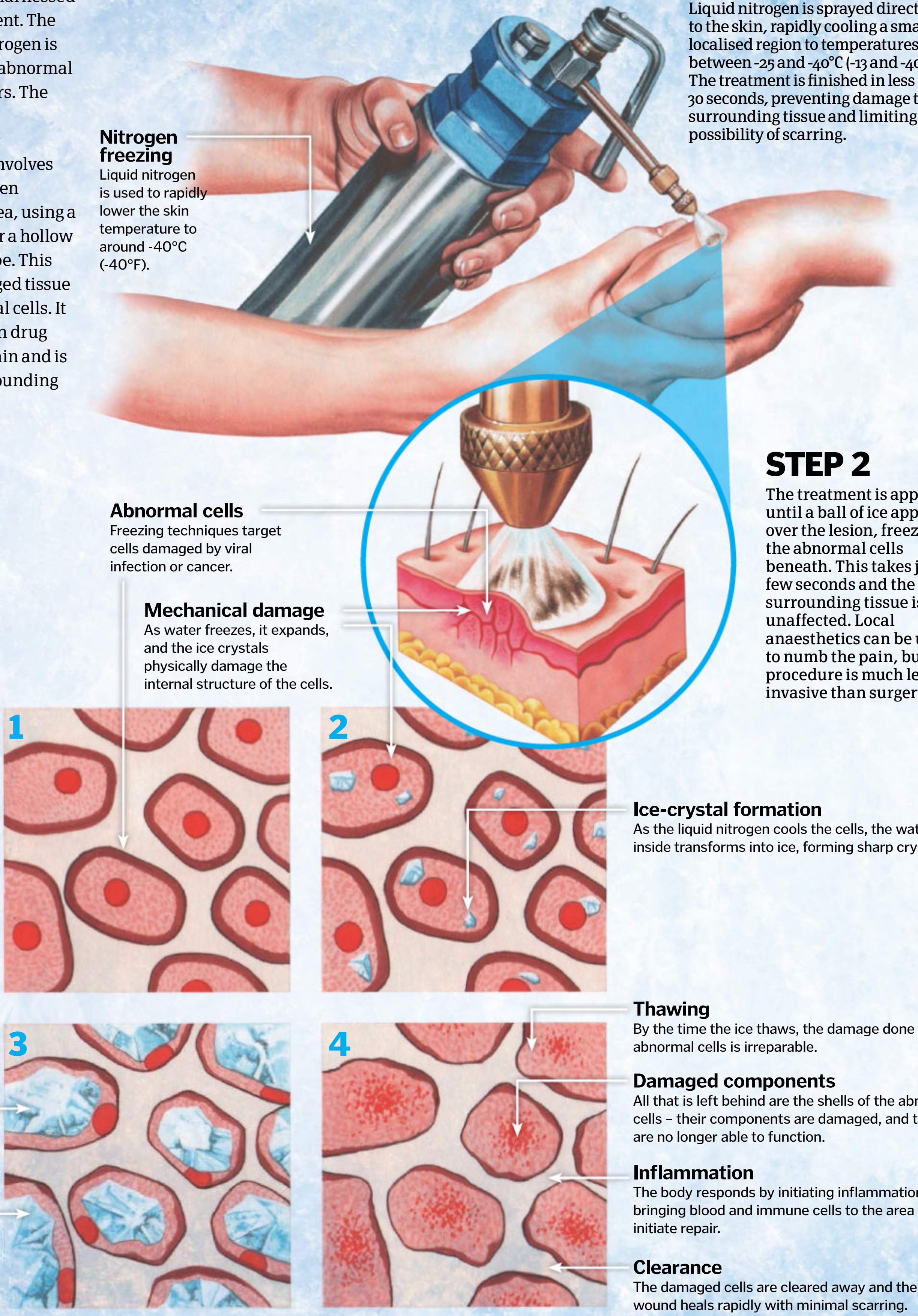
Cryotherapy is being researched for its use in treating illnesses such as arthritis. Exposure to low temperatures slows down nerve conduction, helping to reduce muscle spasm by decreasing the rate of firing of the muscle spindles. This effect is easy to see in your own body – just try undoing the buttons on your coat with frozen fingertips after you come in from the cold.

Cold temperatures are also thought to decrease the activity of damaging enzymes present within arthritic joints, known as collagenases, which break down the protective collagen cartilage that covers the bones.

Studies in patients with a variety of joint disorders have shown that these techniques can temporarily reduce pain for periods of around 90 minutes, allowing patients to undergo physiotherapy and other interventions, which might otherwise have been too uncomfortable. So although it does not have a long-term effect, when used in conjunction with other therapies, there is the potential for significant medical benefit.

CRYOSURGERY

The damaging effects of cryogenic temperatures have been harnessed for use in medical treatment. The extreme chill of liquid nitrogen is routinely used to destroy abnormal cells, from warts to cancers. The technique varies slightly depending on the specific condition, but generally involves applying the liquid nitrogen directly to the affected area, using a cotton bud, a spray gun, or a hollow tube known as a cryoprobe. This rapidly freezes the damaged tissue and destroys the abnormal cells. It is much more specific than drug treatment, causes little pain and is less traumatic to the surrounding tissue than surgery.



STEP 1

Liquid nitrogen is sprayed directly on to the skin, rapidly cooling a small, localised region to temperatures between -25 and -40°C (-13 and -40°F). The treatment is finished in less than 30 seconds, preventing damage to the surrounding tissue and limiting the possibility of scarring.

Nitrogen freezing
Liquid nitrogen is used to rapidly lower the skin temperature to around -40°C (-40°F).

STEP 2

The treatment is applied until a ball of ice appears over the lesion, freezing the abnormal cells beneath. This takes just a few seconds and the surrounding tissue is unaffected. Local anaesthetics can be used to numb the pain, but the procedure is much less invasive than surgery.

Abnormal cells
Freezing techniques target cells damaged by viral infection or cancer.

Mechanical damage
As water freezes, it expands, and the ice crystals physically damage the internal structure of the cells.

STEP 3

As water freezes, it expands, forming jagged crystals, which burst through the membranes of the cells, causing irreparable damage. The cells become dehydrated, and by the time the ice thaws, the abnormal cells are already damaged beyond repair, and are cleared away by the body.

Ice-crystal formation
As the liquid nitrogen cools the cells, the water inside transforms into ice, forming sharp crystals.

Chemical damage
The concentrated solutes left behind when the water freezes chemically damage the components of the cell.

Dehydration
As water turns to ice, the dissolved salts, ions and proteins are left behind, leaving the cell dangerously dehydrated.

Thawing
By the time the ice thaws, the damage done to the abnormal cells is irreparable.

Damaged components
All that is left behind are the shells of the abnormal cells – their components are damaged, and they are no longer able to function.

Inflammation
The body responds by initiating inflammation, bringing blood and immune cells to the area to initiate repair.

Clearance
The damaged cells are cleared away and the wound heals rapidly with minimal scarring.

DID YOU KNOW? *The field of cryogenics began in 1877, when Louis-Paul Cailletet and Raoul Pictet liquefied oxygen for the first time*

CRYOPRESERVATION

At very low temperatures, biological processes come almost to a complete stop. Without heat energy, enzyme activity slows down and living cells can be preserved almost indefinitely. However, preparing living cells for cryopreservation is far from simple. The delicate microscopic structures of cells can be torn to shreds as water freezes, and as the pure water forms ice, dissolved ions, salts and other molecules become concentrated, upsetting the delicate chemical balance inside the cells.

To prevent this, cells are prepared with chemicals known as cryoprotectants. Glycerol, dimethyl sulphoxide (DMSO), or sugars are introduced to replace the water, helping to stop the formation of ice crystals, or to alter their shape and size. Liquid nitrogen is then used to rapidly cool the cells past a point known as the glass transition temperature; at this point, water freezes to form a solid more like glass than ice. The cells can then be stored safely in liquid nitrogen vapour.

Cryopreservation can be used to preserve plants, seeds and even cells

Seeds

Many seeds can withstand the winter cold and, if air-dried, can remain dormant for decades at temperatures of around -18°C (-0.4°F). Cryopreservation is used for long-term storage and protection of valuable or endangered species. The seeds are soaked in glycerol and sucrose for protection against ice and then rapidly frozen in liquid nitrogen.

At the Svalbard Global Seed Vault, precious seeds are stored in man-made caves inside the Arctic permafrost

Blood

Red blood cells have a short life span and in order to supply transfusion demands, whole blood and blood products are cryogenically stored. They are cryopreserved with glycerol and either frozen slowly at -80°C (-112°F), or snap frozen in liquid nitrogen. If they are stored correctly, frozen red blood cells can last for at least ten years.

Donated blood can be kept fresh for years in cryogenic storage

Plants

Many plant tissues can be stored at extremely low temperatures. Plants face the same ice-related dangers as animal cells, and must be prepared before freezing. Many plants already have mechanisms to resist the frost, and preparation techniques vary, including air-drying to remove moisture and submersion in cryoprotectants.

Many plants can withstand freezing temperatures, but for cryogenic storage they need a bit of extra help

Cells

Single cells, from bacteria to human sperm, are now routinely frozen for long-term storage in liquid nitrogen. Cryoprotectants are used to prevent damage from the near-absolute cold, but the chemicals used are sometimes toxic, so a careful balance must be achieved to ensure that the cells can be thawed successfully for use later.

Sperm is stored in liquid nitrogen for use in assisted reproduction and IVF

HUMAN
ORGAN
FOR TRANSPLANT

Is it possible to freeze whole organs?

Cryogenic techniques could prolong organ survival time for transplants

Scientists are now able to reliably freeze and thaw single cells, replacing the water with cryoprotectants to prevent the damaging formation of ice, but freezing entire organs is not so simple. The cells within an organ are so closely packed together that it is much more difficult to protect them all, leaving many vulnerable to ice crystals. During the freezing process, ice forms in the blood vessels, damaging their structure, and it creeps between cells, prising them apart and leading to micro-fractures.

In 2002, Greg Fahy and his team at 21st Century Medicine in California achieved something unusual. They cooled a rabbit kidney to -130 degrees Celsius (-202 degrees Fahrenheit) for 20 minutes, thawed it and successfully transplanted it into a living rabbit.

They used a solution known as M22, which helps water turn to a glass-like solid at low temperatures. They pumped the liquid through the blood vessels in the kidney, allowing it 25 minutes to reach all the cells, and then rapidly froze it using nitrogen vapour. They then gradually warmed the kidney back to normal temperature, using even more of the protective fluid as it thawed.

This finding was a one-off and has not since been repeated, but it shows the idea of preserving organs by freezing is potentially a viable one.

Today, researchers continue to work on the problem, taking inspiration from antifreeze proteins made by animals resistant to the extreme temperatures of polar ice, and using cutting-edge technology to watch how water behaves inside organs they freeze.

Preserving entire organs is a complex challenge, and although it is still a distant dream at the moment, cryogenic techniques could significantly extend the life of organs destined for transplant in the future.

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Space salad

How to grow vegetables that are out of this world

Deliveries of fresh fruit and vegetables are rare on the ISS, so astronauts' diets mostly consist of pre-packaged, non-perishable foods. However, thanks to the Vegetable Production System, or Veggie, being used on board, this is starting to change.

The Veggie plant growth chamber uses plant pillows: small bags of slow-release fertiliser and a clay-like soil that is also used on baseball fields. These pillows are placed in a reservoir of water and have wicks inserted into them to draw the liquid into the soil. Plant seeds are glued onto these wicks to make sure they grow the right way up in the zero gravity environment – that the roots grow down into the soil and the shoots pop out the top of the pillows.

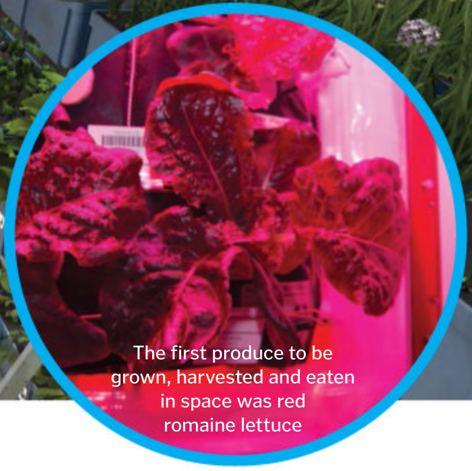
At the top of the chamber, LEDs provide light for photosynthesis as well as a sense of direction to keep the shoots growing upwards. A mixture of red and blue light is used as these are the colours of light plants use most, but the resulting purple hue makes the plants appear grey and unappetising. Therefore, to make their crops look more appealing, the astronauts can switch on additional green LEDs, which combine with the red and blue to create a more natural white light. The first Veggie crop was harvested in 2014 but it had to be frozen and returned to Earth for analysis to make sure it was safe to eat. Once approved for consumption, a second crop was grown and on 10 August 2015, the Expedition 44 crew became the first humans to sample space-grown produce.

Veggie benefits

Growing vegetables on the ISS doesn't just have nutritional benefits for the crew; it can also improve their psychological wellbeing too. A bit of greenery provides some relief from the metallic, lifeless environment of the space station and allows the astronauts to form a connection with a living thing. This will be particularly important for the deep space missions to an asteroid, and then Mars, that NASA is currently planning. For small crews, living in a confined space with limited communication for an extended period of time, having a little piece of Earth to care for will help them cope with the stressful and isolated environment, as well as provide them with a sustainable food source. The tech used in the Veggie system is also proving useful much closer to home, with countries such as Dubai using it to maintain a controlled plant-growing environment in their hot and dry climates.

Growing plants in space has nutritional and psychological benefits for astronauts

Future spacecraft heading on deep space missions could have entire gardens on board



The first produce to be grown, harvested and eaten in space was red romaine lettuce

The history of space food

1962-1964

The first space foods were pastes that were squeezed from tubes and cubes of dehydrated food that were rehydrated by saliva in the mouth.

1965-1967

NASA's Gemini missions had freeze-dried meals, including shrimp cocktail and butterscotch pudding, which were rehydrated by injecting water into the packet.

1968-1972

The Apollo missions were the first to have hot water, which made rehydrating food easier, and utensils in the form of spoons.

1973-1979

The Skylab space station had a dining table, onboard refrigeration, food warming trays and 72 different food items.

1980-1999

Astronauts on the Space Shuttle missions could design their own menus and heat their food in an onboard oven.

2000-today

On the ISS, the menu consists of frozen, refrigerated and ambient foods, and sometimes meals designed by celebrity chefs.

© NASA

DID YOU KNOW? *Ancient fingerprints have been found on the walls of Egyptian tombs*

ATE OF BIRTH
MM DD YY
SEX
RACE
HEIGHT
WEIGHT
EYES
9. L. RING
5. R. L

Intelligent fingerprinting

The tech that enables illegal substances to be detected with just a fingerprint

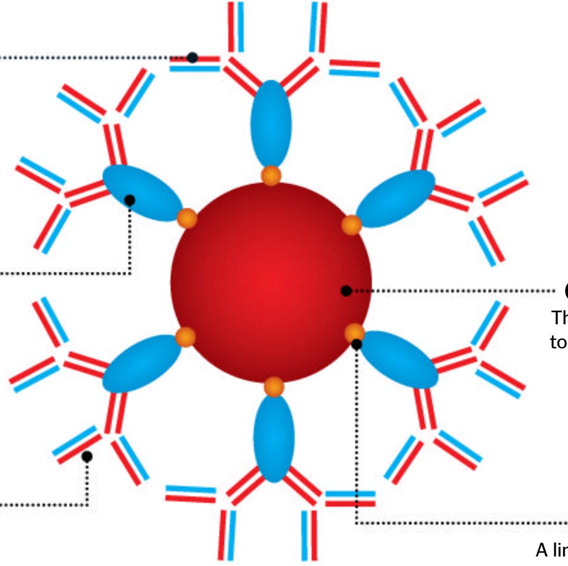
The University of East Anglia in the UK has developed a handheld device that detects the breakdown products of commonly abused drugs in sweat released from pores in the fingertips.

An image of the fingerprint is taken to create a reference point and treated with a solution containing gold nanoparticles, which stick to the breakdown products of illicit substances. The particles are stained with a fluorescent dye and a second image of the print is taken.

This test is far quicker than alternative methods and it also provides proof that a positive result belongs to the owner of the fingerprint and is not down to sample contamination. Sweat is released from pores in the fingertips and finally tracks along the fingerprint ridges, carrying with it traces of drug metabolites that gradually decrease in concentration. If the staining of the print is greatest at the pores, it provides solid evidence that the metabolites are being released from the sweat glands of the person being tested.

Nanoparticle drug testing

The test takes advantage of biology, using antibodies to detect the products of drug breakdown



Antibody
Antibodies are generated by the immune system and can be manufactured in the laboratory to stick to almost any target.

Protein
In combination with the linker molecule, proteins are used to bind the antibodies to the gold nanoparticle.

Detection
Antibodies stick specifically to the metabolites of commonly abused substances.

Gold nanoparticle
The entire complex is held together using biologically inert gold particles.

Linker
A linker molecule is used to attach the antibodies to the gold nanoparticle.

© Thinkstock; Safe-Rain Corporation

How water is treated

The cleaning process that makes water safe to drink explained

The water that comes flowing out of your tap starts off as rain falling from the sky. It's collected in rivers and lakes as surface water, or beneath the Earth's surface as groundwater, but it would be unsafe to drink without treatment. This water contains dirt, pollutants and microorganisms that cause nasty diseases such as typhoid, cholera and dysentery. To remove these harmful impurities, drinking water is filtered and disinfected at a water treatment plant before it reaches your home.

The treatment process is often tailored to each water source, as some require more cleaning than others. For example, as groundwater is partially filtered when it trickles through soil and rock in the earth, it typically requires less treatment after it is pumped out of the ground. However, surface water must go through a few more stages of cleaning to remove large debris as well as smaller impurities. Some treatment plants also add extra ingredients to water, such as fluoride to help prevent tooth decay, or lime to soften it by removing calcium compounds.

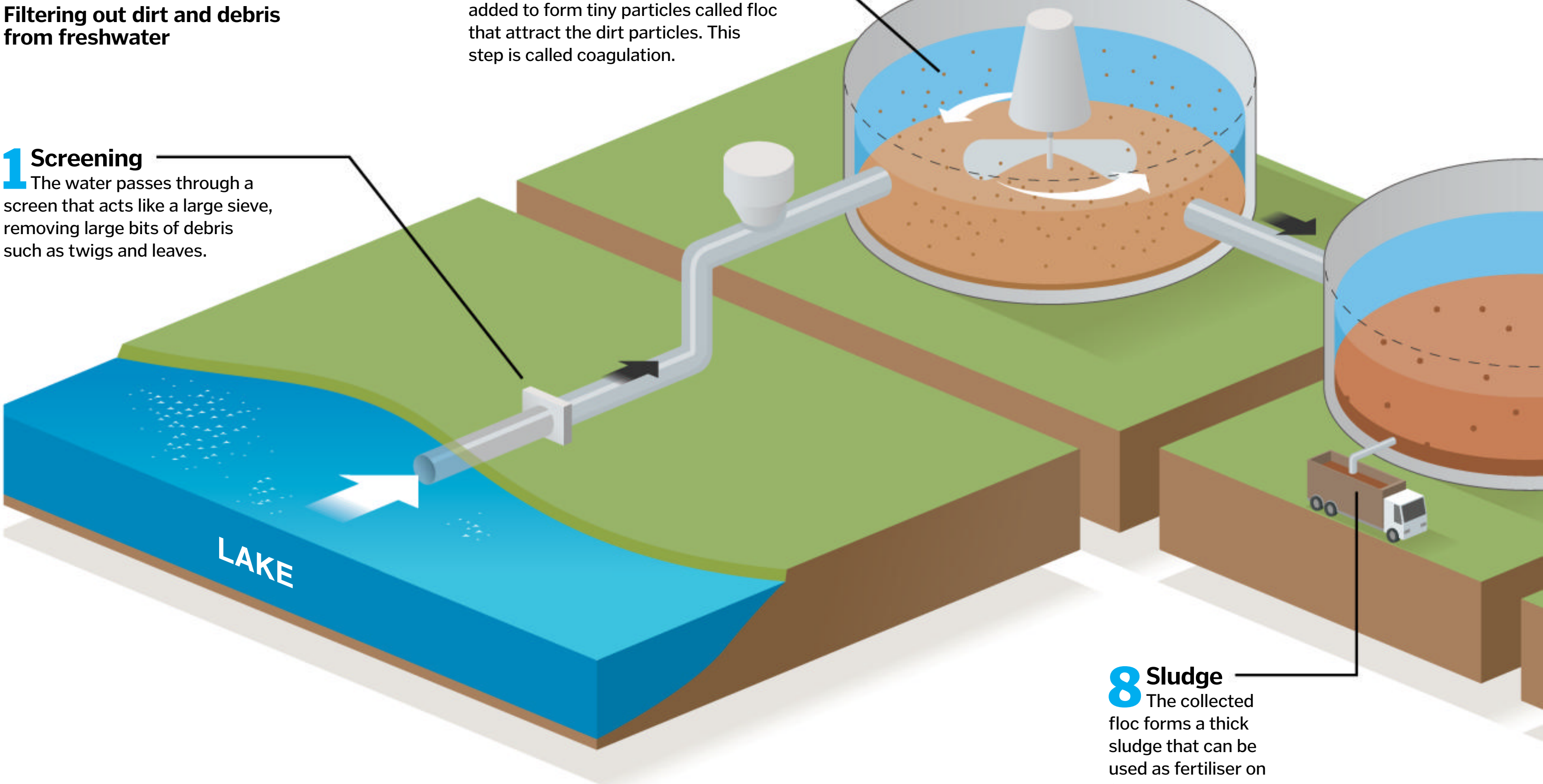
Every time you have a glass of clean drinking water, you have the engineers that develop these water treatment facilities to thank for making it safe. They are continuously testing new methods for treating water that are cheaper and more energy efficient. One such method is solar disinfection, which involves using UV radiation from the Sun to damage and kill harmful bacteria in the water.

Engineers test and tweak the treatment process to make sure your water is safe to drink

Sedimentation takes place in large round tanks called clarifiers

From lake to tap

Filtering out dirt and debris from freshwater



1 Screening The water passes through a screen that acts like a large sieve, removing large bits of debris such as twigs and leaves.

2 Removing dirt Alum and other chemicals are added to form tiny particles called floc that attract the dirt particles. This step is called coagulation.

8 Sludge The collected floc forms a thick sludge that can be used as fertiliser on farms and gardens.

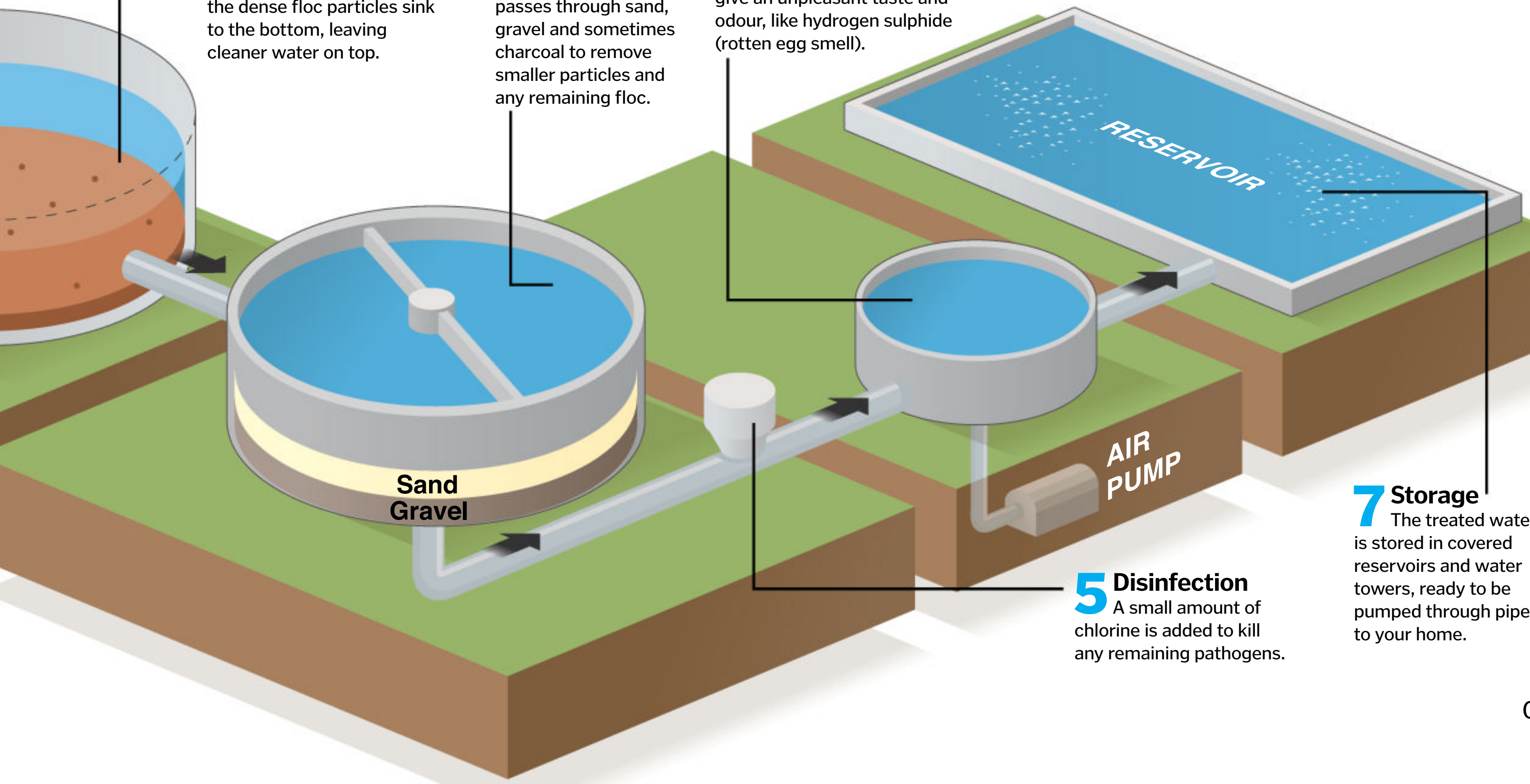
DID YOU KNOW? *97% of the world's water is salty and undrinkable, 2% is frozen as ice, leaving 1% for human needs*

Hard & soft water

Rainwater is naturally weakly acidic and considered 'soft'. However, as it flows over and through the land, mineral compounds from rocks dissolve into the water. The most common are calcium and magnesium ions from chalk and limestone, and it's these that make the water more alkaline and 'hard'. Although hard water often tastes better than soft water and the minerals it contains are good for our bones and teeth, it also has several drawbacks. For example, when soap is added to hard water, more soap is needed to form a decent lather, and when the mineral ions react with the soap they leave behind an unsightly scum on your bath or shower. Plus, when hard water it heated, it produces limescale, which can coat the heating elements of kettles and washing machines to reduce their efficiency. The hardness of your water will depend on the geology of your local area and whether or not the treatment plant has softened it before delivering it to your home.

Some household appliances use ion exchange resins to soften water and prevent limescale

> *"Every time you have a glass of clean drinking water, you have the engineers to thank for making it safe"*



3 Removing solids The water flows through a sedimentation tank where the dense floc particles sink to the bottom, leaving cleaner water on top.

4 Filtration The water then passes through sand, gravel and sometimes charcoal to remove smaller particles and any remaining floc.

6 Aeration Air is forced through the water to remove gasses that can give an unpleasant taste and odour, like hydrogen sulphide (rotten egg smell).

5 Disinfection A small amount of chlorine is added to kill any remaining pathogens.

7 Storage The treated water is stored in covered reservoirs and water towers, ready to be pumped through pipes to your home.

Image by Acute Graphics
© Thinkstock

LIFE-SAVING TECHNOLOGY

Discover amazing new medical techniques for saving lives today and in the future

Developments in technology have already enabled a great deal of significant life-saving advances in medicine. From defibrillators that can restart your heart to X-ray scanners that enable a fast and accurate diagnosis of broken bones, humans have never been so well equipped in the fight against deadly diseases, infections and illnesses.

However, there is still a lot more that can be done. New methods for improving medical practices, procedures and equipment are constantly being trialled and tested to provide much-needed solutions for doctors and patients alike, and we are already seeing some exciting new developments that could completely change the way life-threatening conditions are treated.

For example, 3D printing is already saving lives by way of made-to-measure implants designed using the patient's own anatomy, but it still has the potential to save even more lives in the near future as the possibility of printing entire human organs is quickly starting to become reality.

One area that has inspired a lot of innovation is the battle against cancer, and new tools, such as a surgical iKnife that can sniff out cancerous tissue, and a miniature microscope that can identify whether it is malignant or benign, have already been created to fight it. In the future though, the cure of cancer is likely to come on an even smaller scale. Nanorobots roughly the size of bacteria could soon be injected into our bodies to seek out diseased tissue or cells and break them down or alter them so that they are no longer harmful.

DID YOU KNOW? *Scientists have already worked out how to bioprint vascular networks, needed to supply organs with blood*

3D PRINTING

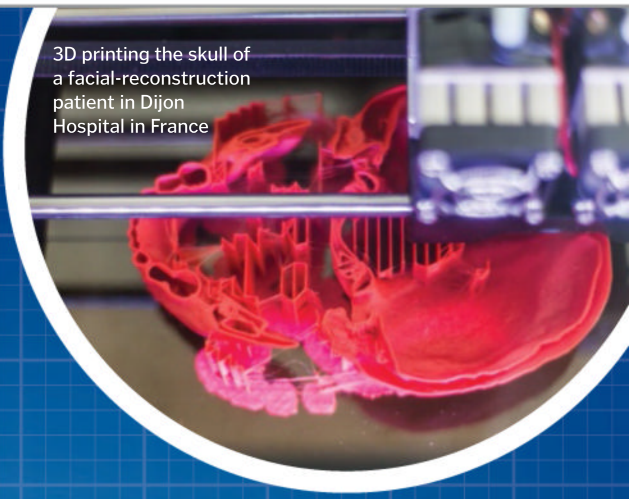
Will printing replacement organs become a reality?

3D printing isn't just for creating car parts or toys; it is hugely beneficial for medical procedures too. Facial-reconstruction surgery is one such procedure that has been revolutionised by the 3D printer.

From CT scans of a patient's head, doctors can print a 3D model of their skull and use it to design custom plates, which they can then print out and use to rebuild the patient's face. As well as enabling them to create more accurate implants, they can also print guides that help them cut and reposition the existing bone more precisely.

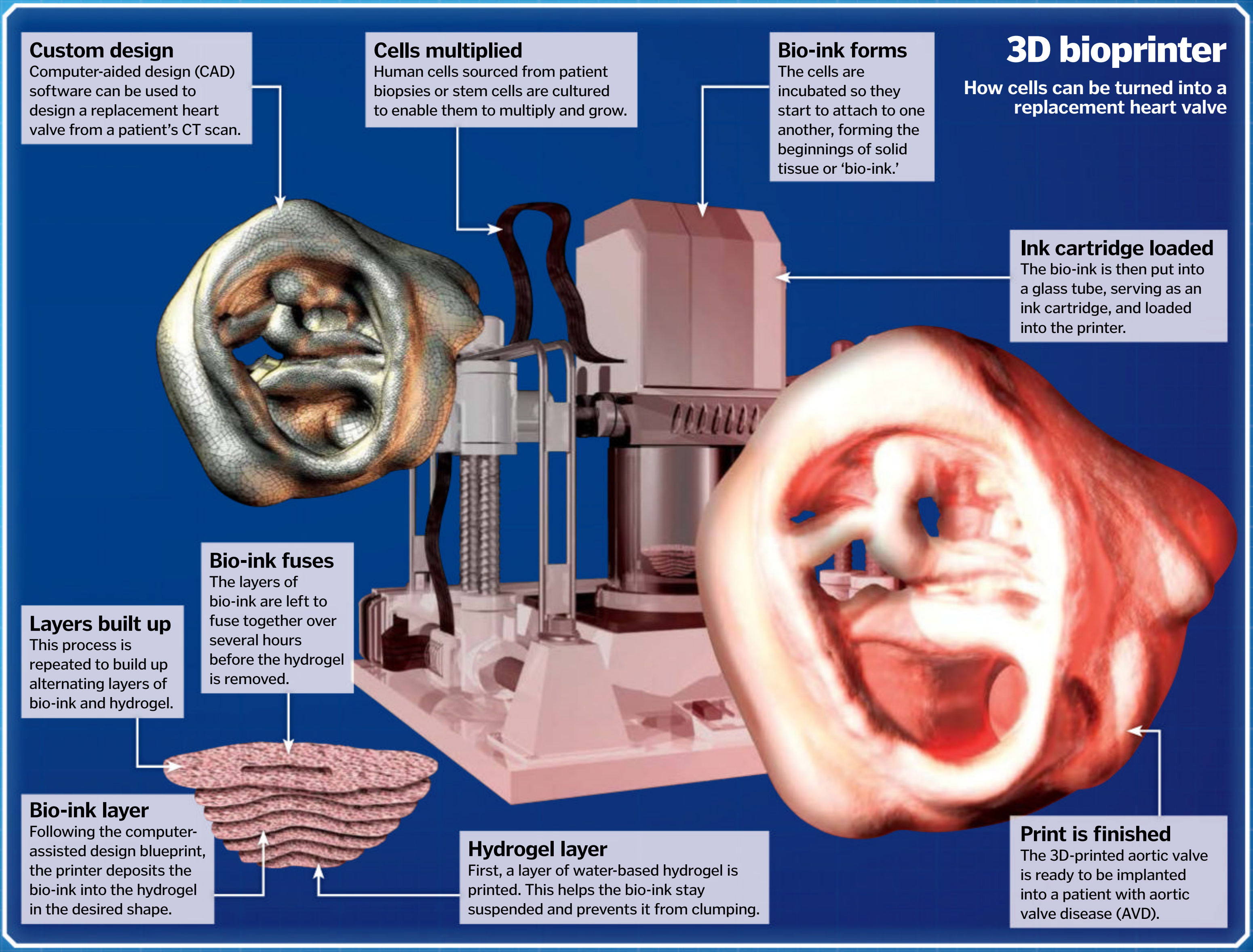
3D printing has also been used to save the lives of babies with severe tracheobronchomalacia, a condition that occurs when the airway walls are weak and collapse, blocking airflow to the lungs. To solve the problem, doctors at the University of Michigan used a laser-based 3D printer to create a tracheal splint. The splint was then sewn around the child's airway to act as a skeleton to aid proper growth. After two or three years, the trachea grows into a healthy state and the splint is reabsorbed by the body.

This technology is not just limited to implants, either. 3D bioprinters build up layers of human cells to create tissue. So far, this printed tissue has only been used to discover and test new drugs and investigate the causes of human disease, but scientists believe it could soon be used to print replacement parts and eventually entire organs for the thousands of patients that are waiting for transplants.



3D printing the skull of a facial-reconstruction patient in Dijon Hospital in France

The 3D-printed skull of a patient needing facial-reconstruction surgery, used to mould custom implants



3D bioprinter

How cells can be turned into a replacement heart valve

Custom design
Computer-aided design (CAD) software can be used to design a replacement heart valve from a patient's CT scan.

Cells multiplied
Human cells sourced from patient biopsies or stem cells are cultured to enable them to multiply and grow.

Bio-ink forms
The cells are incubated so they start to attach to one another, forming the beginnings of solid tissue or 'bio-ink.'

Ink cartridge loaded
The bio-ink is then put into a glass tube, serving as an ink cartridge, and loaded into the printer.

Hydrogel layer
First, a layer of water-based hydrogel is printed. This helps the bio-ink stay suspended and prevents it from clumping.

Bio-ink layer
Following the computer-assisted design blueprint, the printer deposits the bio-ink into the hydrogel in the desired shape.

Layers built up
This process is repeated to build up alternating layers of bio-ink and hydrogel.

Bio-ink fuses
The layers of bio-ink are left to fuse together over several hours before the hydrogel is removed.

Print is finished
The 3D-printed aortic valve is ready to be implanted into a patient with aortic valve disease (AVD).

© Rex Features; Corbis

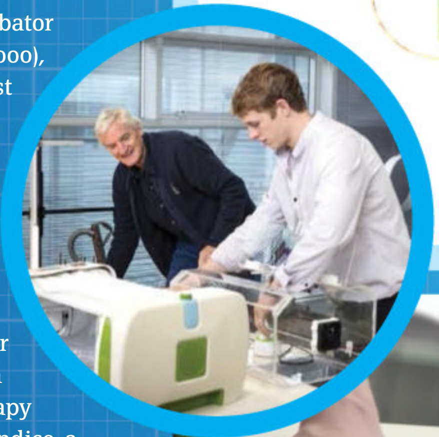
INFLATABLE INCUBATOR

A low-cost invention that could give premature babies in developing countries a better chance at life

More than one in ten babies worldwide are born prematurely, but in developing countries, the equipment just isn't available to give those babies a fighting chance of survival. 75 per cent of deaths resulting from premature birth could be avoided if inexpensive treatments were more readily available, which is why a new inflatable incubator called MOM could revolutionise third-world care.

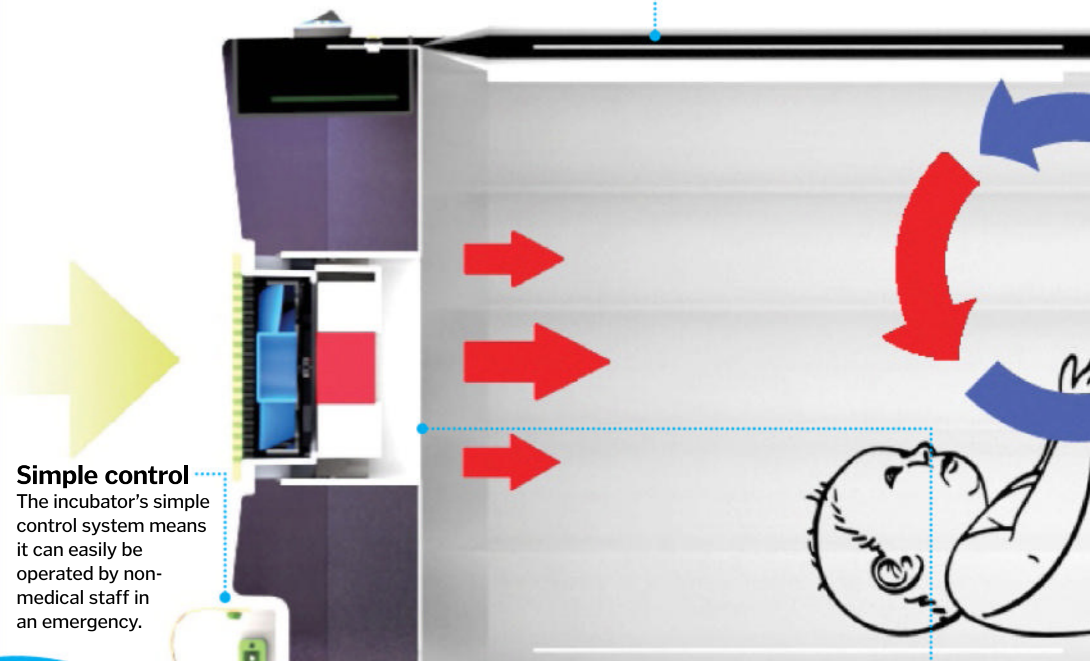
The inventor of this new machine is 23-year-old James Roberts. During the final year of his Product Design and Technology degree at Loughborough University, James was given a brief to design something that solved a problem. He chose to try and help the thousands of babies that are born too early in refugee camps across the world each year. As opposed to a normal incubator that costs upward of £30,000 ($47,000), James's portable solution costs just £250 ($390) to manufacture, test and transport to a desired location. MOM got its name because it acts as a surrogate womb for premature babies. As well as providing a stable-heat environment for the infant, it also uses humidifiers to keep their skin moist and prevent them from losing fluids. A built-in phototherapy lamp can also be used to treat jaundice, a condition that can effect any newborn, not just premature infants. It works by emitting a specific wavelength of light that lowers the bilirubin levels in the baby's blood using a process called photo-oxidation. This converts the bilirubin into a substance that can dissolve easily in water, so that the baby's liver can then break it down and remove it.

James's invention won him the 2014 James Dyson Award for design, with a £30,000 ($47,000) prize to help him develop and test his prototype further. He hopes the final version will be ready for mass production by 2017 and help save lives across the world.



How MOM works

Inside the inflatable incubator prototype



Sanitary environment
Not only is the PVC ribbing a great insulator, it is also easy to wipe down and sterilise.

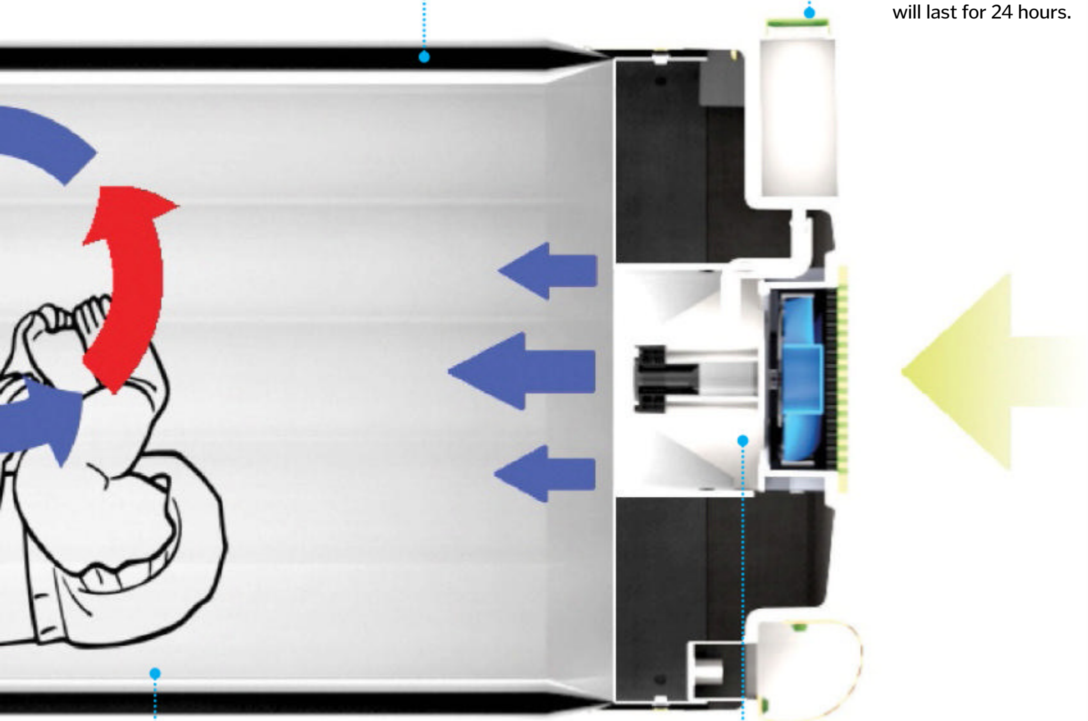
Simple control
The incubator's simple control system means it can easily be operated by non-medical staff in an emergency.

Control unit
The main control unit contains an Arduino computer that regulates temperature, humidification and the phototherapy lamp.

Heating element
Ceramic heating elements at each end of the incubator provide a stable heat environment that can be controlled.

Transparent panels incorporated into the incubator allow for easy access to the child inside

DID YOU KNOW? *On average, 12% of babies born in the poorest countries are premature, compared to 9% in richer countries*



Inflatable body
The main body of the incubator is made from inflatable PVC ribbing, which is very cheap and lightweight.

Power source
Power can come from a variety of power sources, such as a car battery that will last for 24 hours.

Portable design
The PVC ribbing can be manually inflated and deflated, allowing it to fold down into a handy carrying case.

Air circulation
Each heater is accompanied by a fan, which helps to evenly circulate the warm air around the incubator.

One-on-one with an inventor

James Roberts reveals the story behind his creation

James's creation costs less than 1% of a standard incubator and is much easier to transport

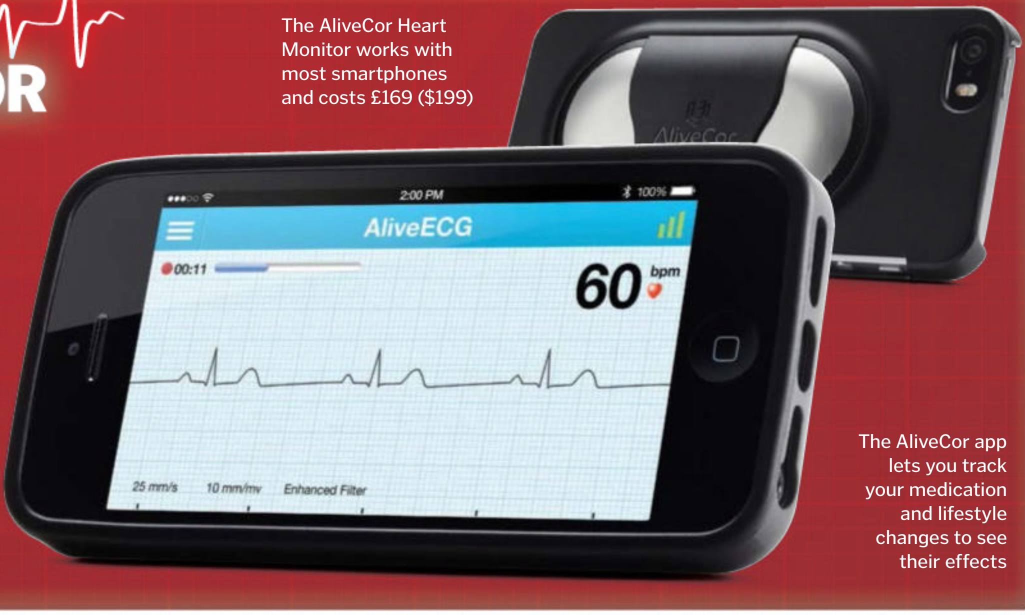
What was it that inspired you to design an inflatable incubator?
One night I sat down in front of my TV in my student flat and a programme about Syria came on. There was a five-minute segment in that programme showing all these premature kids that are dying just because they don't have any incubators out there. I thought there has got to be a better way of doing it and so decided to try and redesign the incubator.

How did you start developing your idea?
I did as much internet research as I could and downloaded instruction manuals from old incubators. I also went to neonatal experts who told me what it really needed, and people who had worked in refugee camps who told me what the real problems out there were.

Did you face any problems throughout the process?
A lot of doctors I was speaking to told me I shouldn't do this; that other people hadn't been able to innovate in this field, so what makes me think I could do it? There were lots of people telling me I should do something else in my final year and not waste my time, but I thought, no, I'm going to try anyway.

SMARTPHONE HEART MONITOR

AliveCor is a heart-rate monitor that attaches to your smartphone. It records the electrical impulses that spread through the heart to make it contract by measuring your pulse through your fingers. You simply rest your fingers on the monitor and it will record this electrical activity via an electrocardiogram (ECG). After just 30 seconds, the AliveCor app will alert you if atrial fibrillation – a heart condition that causes an irregular and often abnormally fast heart rate – is detected. The innovative app also lets you keep track of and archive all your past ECGs and share them with your doctor between appointments.



The AliveCor Heart Monitor works with most smartphones and costs £169 ($199)

The AliveCor app lets you track your medication and lifestyle changes to see their effects

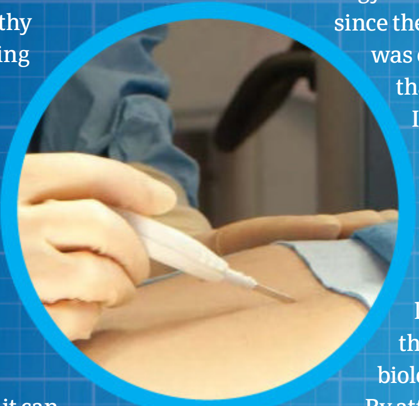
© Dyson;

THE CANCER-SENSING iKNIFE

The intelligent surgical knife that can instantly detect cancerous tissue

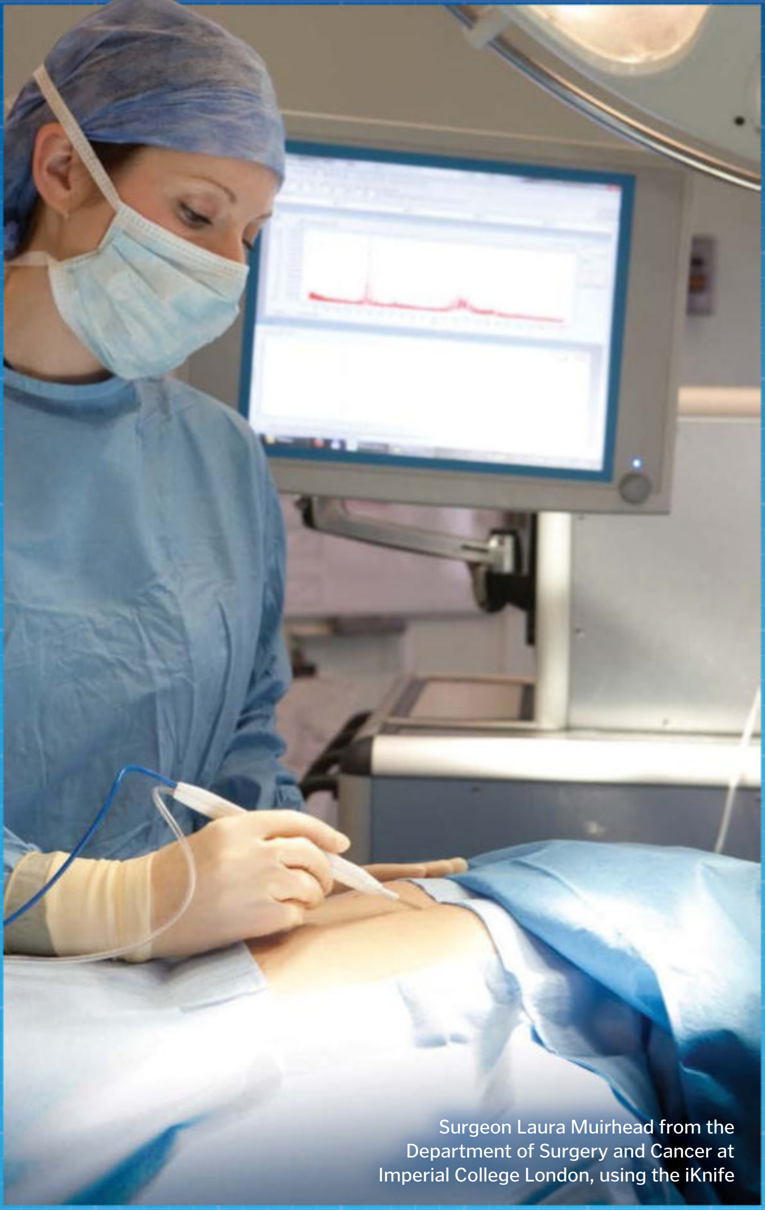
When removing tumours, it is quite common for bits of cancerous tissue to be left behind, which can then cause the tumour to regrow.

As it is usually impossible to tell which tissue is cancerous by sight, surgeons will often take out some of the healthy tissue surrounding the tumour to make sure they get it all. They can even send the removed tissue to be tested in the lab while the patient remains under general anaesthetic, but it can take up to 30 minutes to receive the results.



Even with these measures, one in five breast cancer patients who have surgery still require a second operation to fully remove the cancer. However, the iKnife could greatly improve accuracy and help them get the whole thing removed in a single operation.

The iKnife is a modified electrosurgical knife that uses heat to cut through tissue and minimise blood loss. This technology has been around since the 1920s, but it was only recently that Dr Takats of Imperial College London realised its full potential. The smoke given off as the knife vaporises the tissue holds biological info. By attaching a mass spectrometer that detects the different profiles of chemicals in the smoke, the iKnife can then match its readings to a reference library of thousands of cancerous and non-cancerous tissues to determine which it is cutting in less than three seconds.

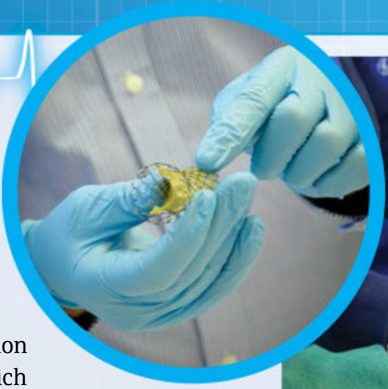


Surgeon Laura Muirhead from the Department of Surgery and Cancer at Imperial College London, using the iKnife

REPLACEMENT AORTIC VALVE

Revolutionary new system will treat aortic stenosis in the elderly

Aortic stenosis (AS) occurs when the aortic valve in the heart is narrowed, making it difficult for it to pump blood through the body. If left untreated it can prove fatal, but replacing the valve typically requires open-heart surgery, which is deemed too high risk for a third of patients. An alternative is Transcatheter Aortic Valve Implantation (TAVI), which can be conducted under local anaesthetic. It involves inserting the CoreValve Evolut R transcatheter valve into the leg, neck or chest and feeding it up to the heart, where it can be deployed with a simple EnVeo R Delivery Catheter System.



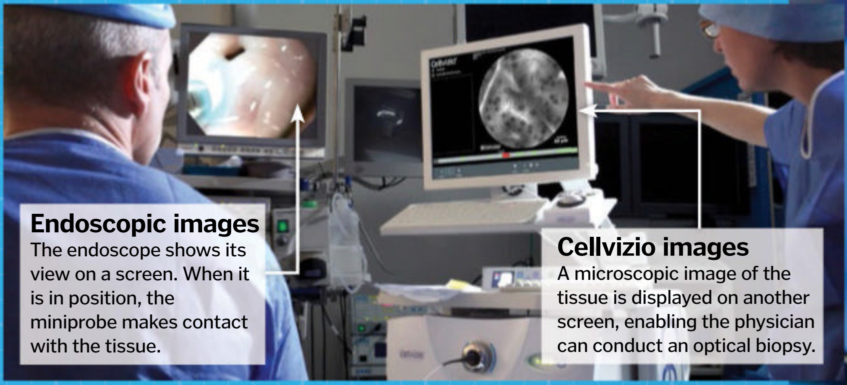
Twisting the handle of the delivery system allows the doctor to deploy or recapture the valve

DID YOU KNOW? *As well as detecting cancerous tissue, the iKnife can also be used to distinguish horse meat from beef*

MINIATURE MICROSCOPE

The tiny instrument that can instantly diagnose cancer

To examine potentially cancerous tissue in the human body and discover whether it is benign (non-cancerous) or malignant (cancerous), doctors would normally have to extract it and look at it under a microscope. However, a new miniature microscope that can be inserted into the patient's mouth or anus while they are conscious provides real-time results in a less invasive manner. The Cellvizio probe, developed by Mauna Kea Technologies, generates an optical biopsy that uses light to be able to see underneath the surface of tissue and examine individual cells during an endoscopy. This allows the physician to diagnose patients more quickly, so that they can begin treatment sooner and have a better chance of recovery. It's not just cancer tissue that can be examined, either, as the Cellvizio probe can also be used for deep brain imaging, to examine drug delivery and visualise infectious diseases.

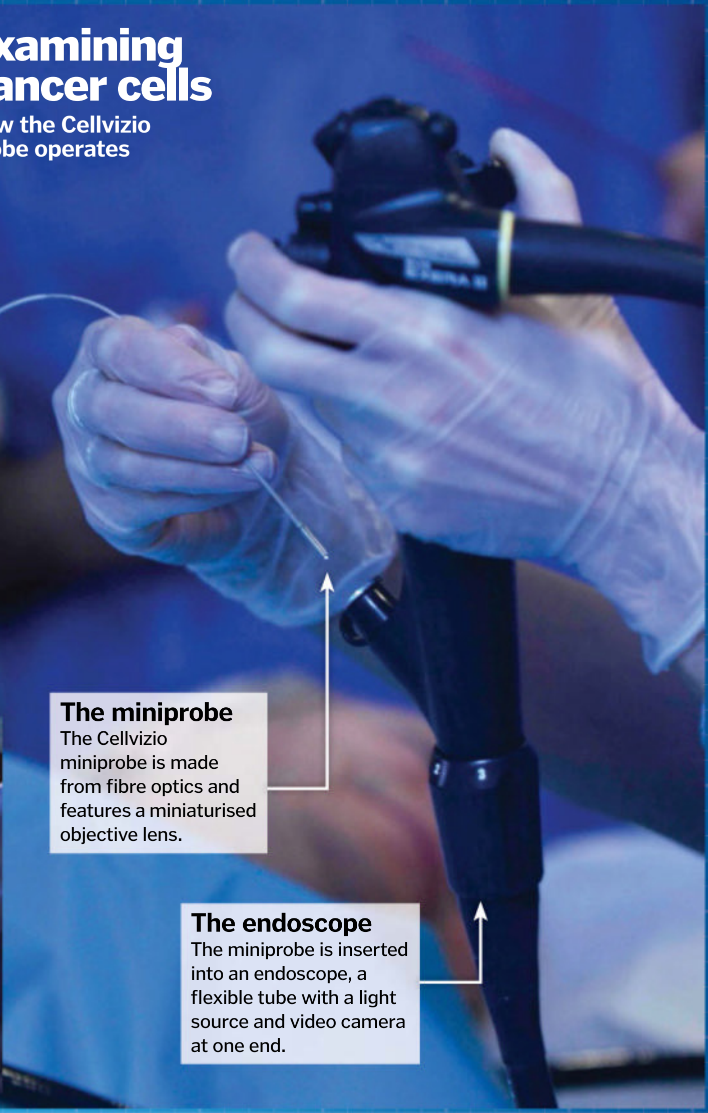


Endoscopic images
The endoscope shows its view on a screen. When it is in position, the miniprobe makes contact with the tissue.

Cellvizio images
A microscopic image of the tissue is displayed on another screen, enabling the physician can conduct an optical biopsy.

Examining cancer cells

How the Cellvizio probe operates

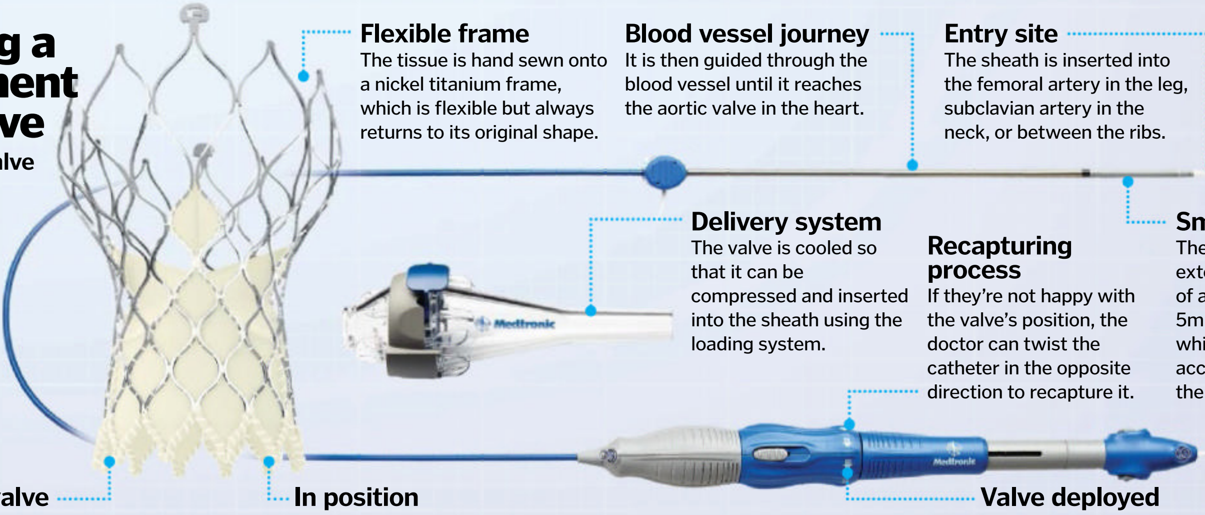


The miniprobe
The Cellvizio miniprobe is made from fibre optics and features a miniaturised objective lens.

The endoscope
The miniprobe is inserted into an endoscope, a flexible tube with a light source and video camera at one end.

Deploying a replacement heart valve

Inside the CoreValve Evolut R system



Flexible frame
The tissue is hand sewn onto a nickel titanium frame, which is flexible but always returns to its original shape.

Blood vessel journey
It is then guided through the blood vessel until it reaches the aortic valve in the heart.

Entry site
The sheath is inserted into the femoral artery in the leg, subclavian artery in the neck, or between the ribs.

Delivery system
The valve is cooled so that it can be compressed and inserted into the sheath using the loading system.

Recapturing process
If they're not happy with the valve's position, the doctor can twist the catheter in the opposite direction to recapture it.

Small profile
The sheath has an external diameter of approximately 5mm (0.2in), which improves access through the blood vessel.

Transcatheter valve
The CoreValve Evolut R transcatheter valve is made from tissue taken from the pericardium of pigs.

In position
When it is fully deployed, the valve expands and pushes the damaged aortic chambers to the vessel walls.

Valve deployed
Once in position, the doctor twists the catheter to deploy the replacement valve, which slowly expands in warm temperatures.

© Imperial College London

LIFESTYLE

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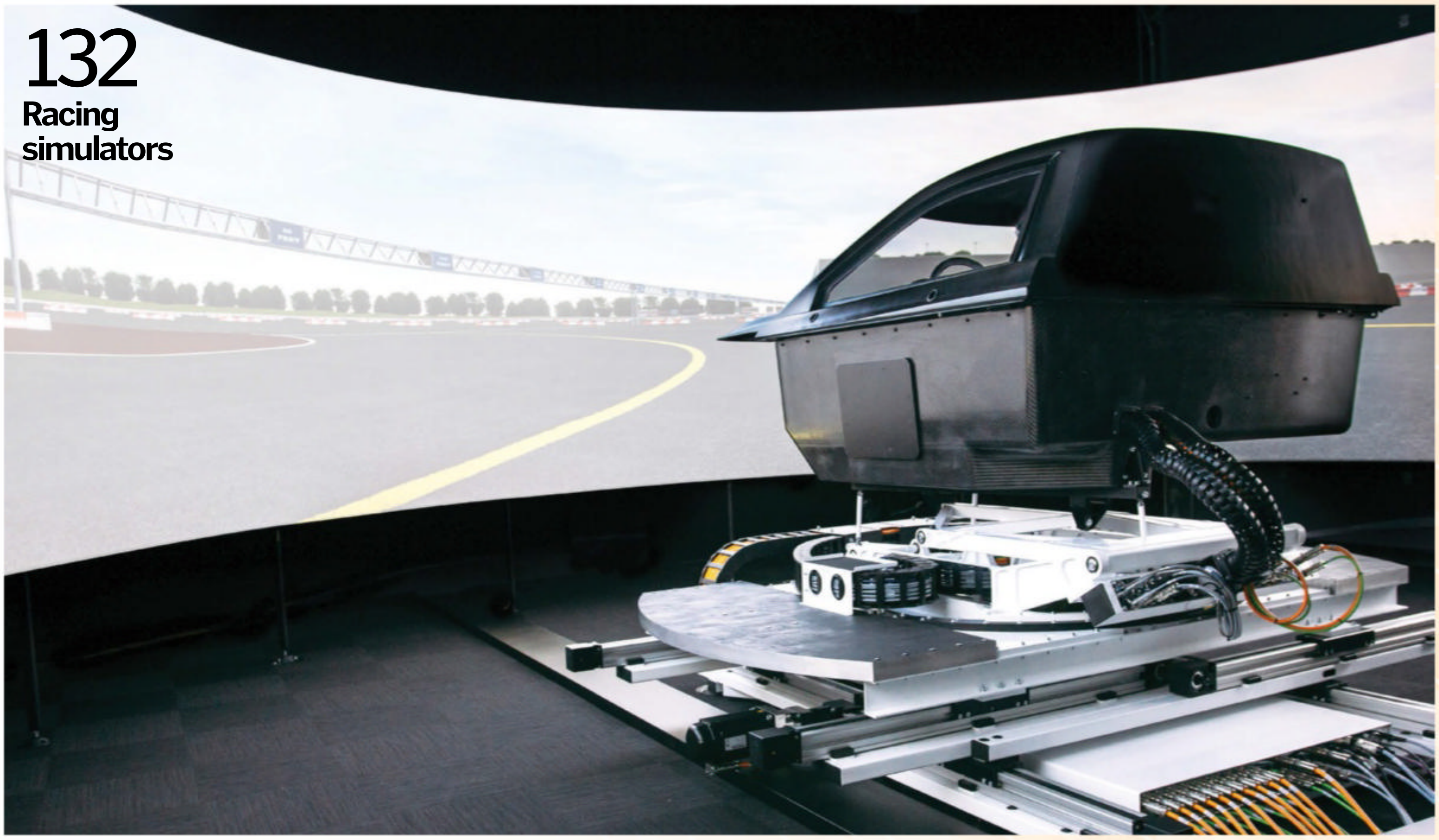

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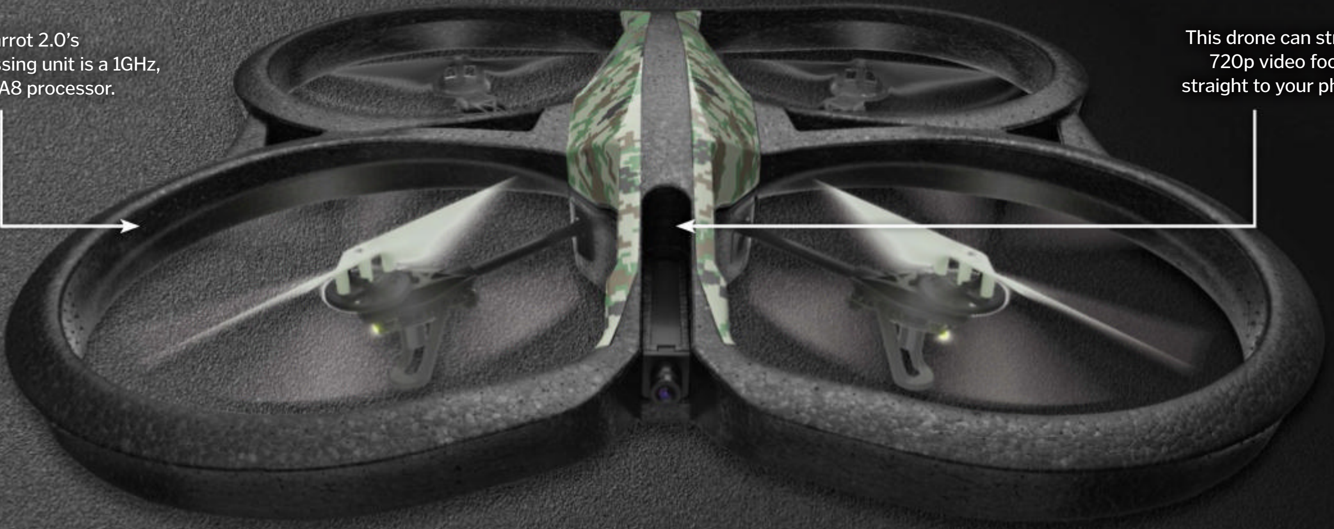
Racing simulators



The Parrot 2.0's processing unit is a 1GHz, 32-bit A8 processor.

This drone can stream 720p video footage straight to your phone.

DRONES

How unmanned flight will change your life

Trimble
UX5

The lightweight expanded polypropylene body helps the UX5 weigh just 2.5kg (5.5lb).

The operator can be 5km (3mi) away from the UX5 and still control it.

The Draganflyer X6 can carry one of several different imaging devices, including a thermal imaging camera.

The Matternet drone can carry up to 2kg (4lb) of medical supplies between ground stations.

If it is flown out of the remote control's range, this drone automatically returns home.

The Phantom 2 Vision+ is capable of shooting 1080p HD video at 30fps.

Drones are being used in air forces around the world, but the future is looking much more varied for the remote controlled aircraft. There is a fast-growing industry of autonomous flight that can both help and entertain the world, from rescuing people at sea to recording awe-inspiring aerial videos.

Disaster relief, for example, is a major area where drones can make an incredible difference. They can fly over the scene of an earthquake, nuclear meltdown or bomb site and capture high-resolution pictures or video to help the team on the ground organise a rescue or clean-up mission. Drones such as the Trimble UX5 could be of enormous benefit as the 2.4-gigahertz modems in the craft and the tablet can communicate over a distance of five kilometres (3.1 miles), enabling mapping to take place with the pilot nowhere near potentially dangerous rubble and aftershocks.

When the Fukushima nuclear power plant malfunctioned in March 2011, clean-ups and analysis of the radiation was limited due to the health risks posed to helicopter pilots.

Drones such as the Advanced Airborne Radiation Monitoring (AARM) system designed by Dr James MacFarlane at the University of Bristol could put an end to that. This particular craft is a hexacopter with a gamma spectrometer attached, which measures the amount of radiation being emitted from a chosen site. This can be done without a human anywhere near the area, so information can be received much more quickly and safely.

One of the most exciting commercial applications of drones is aerial photography and videoing. In the past, shooting any kind of media from the air required the hire of cranes or helicopters. Now, however, drone-mounted cameras can be bought for as little as £50 ($80), enabling amateur photographers and film-makers to capture amazing high-definition footage for a fraction of the cost.

Although drones might seem the futuristic domain of governments, the military and serious enthusiasts, there are a number of extremely practical day-to-day applications they can be used for. Amazon and DHL are both deep into the testing stage of delivery drones. You may remember the end of 2013 when Amazon claimed drones would be delivering small packages within five years.

Drones offer a whole new perspective on video recording and photography

Currently the use of drones for commercial purposes is banned in the United States, but Amazon has petitioned the Federal Aviation Authority (FAA) to relax their rules to allow small drones to carry payloads of 2.3 kilograms (five pounds) to customers. This weight, they say, makes up 86 per cent of their deliveries and would take big, bulky and dangerous delivery vehicles off the road. DHL has already flown test missions from the German mainland to the island of Juist, off its northern coastline.

Commercial drones are a far cry from their headline-grabbing military cousins, but they are every bit as exciting, packed with fascinating technology and the ability to perform tasks that makes our lives, and the world, a little bit safer and a whole lot more fun.

The AARM won its inventor, Dr James MacFarlane, the 2014 ERA Foundation Entrepreneurs Award

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LIFE-SAVERS

Discover the innovative drones designed to rescue those in need

The agility and efficiency of these incredible machines often means they are better equipped than humans or other vehicles for humanitarian tasks . From transporting aid to spotting someone in need, there is a variety of potentially life-saving drone aircraft projects that are currently in development.

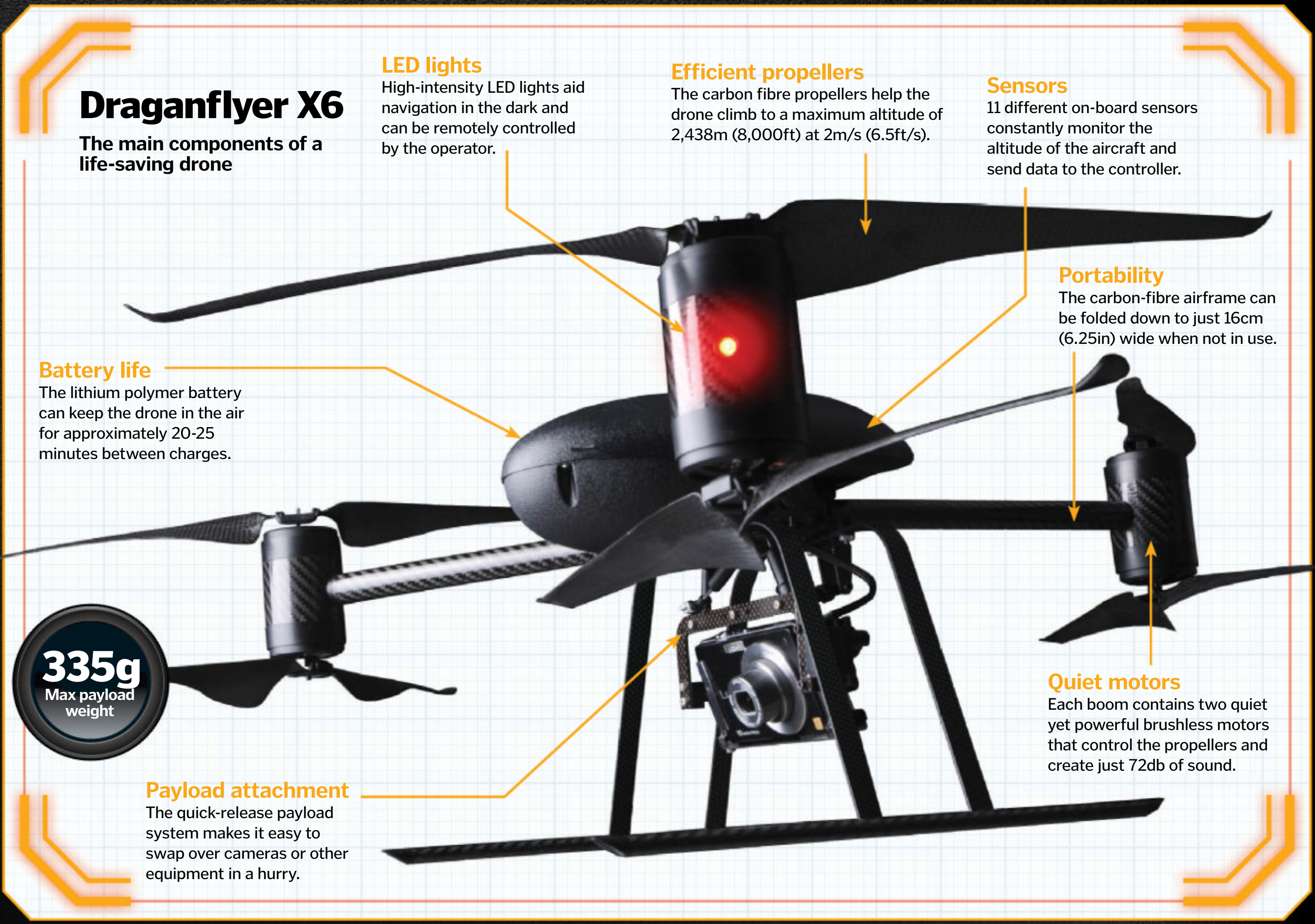
One such initiative is the LifeLine Response app, a personal panic button that will summon a drone if you are in distress. If you are concerned about your safety, you can simply load the app and keep your thumb pressed on the screen or set a timer. If you get into trouble, you can release your thumb or fail to deactivate the timer, and the police will be called and a drone deployed to your location using GPS.

The idea is that the drone, which can travel at 97 kilometres (60 miles) per hour, will be able to scare off an attacker by sounding an alarm, follow them if they flee the scene, and collect information from the area before the police arrive. It is hoped the system could be used in cities across the world, with dozens of drones stationed at each law-enforcement headquarters waiting to spring into action.

Another concept, developed by a young Dutch engineering student named Alec Momont, involves 'ambulance drones' quickly delivering defibrillators to heart-attack victims. The drone would be able to transport the equipment within minutes, and then the operator can use two-way video supported communication in order to instruct a nearby helper to use it.

While some life-saving drones are still a work in progress, others are already being put to work. For example, Draganflyer drones are being used to provide a unique high-resolution view of disaster zones and crash sites to help teams on the ground locate victims, organise rescue missions and document the scene.

Draganflyer makes several different models of drone suited to both hobbyist and professional applications. These come with a choice of camera, including a GoPro and thermal-imaging camera, and are flown using a handheld controller, but you will need some training in order to operate one.



Draganflyer X6

The main components of a life-saving drone

LED lights
High-intensity LED lights aid navigation in the dark and can be remotely controlled by the operator.

Efficient propellers
The carbon fibre propellers help the drone climb to a maximum altitude of 2,438m (8,000ft) at 2m/s (6.5ft/s).

Sensors
11 different on-board sensors constantly monitor the altitude of the aircraft and send data to the controller.

Portability
The carbon-fibre airframe can be folded down to just 16cm (6.25in) wide when not in use.

Battery life
The lithium polymer battery can keep the drone in the air for approximately 20-25 minutes between charges.

335g
Max payload weight

Quiet motors
Each boom contains two quiet yet powerful brushless motors that control the propellers and create just 72db of sound.

Payload attachment
The quick-release payload system makes it easy to swap over cameras or other equipment in a hurry.

DID YOU KNOW? *85 per cent of roads in sub-Saharan Africa are inaccessible in the wet season, making drone delivery useful there*

Draganflyer story

We spoke to Kevin Lauscher from Draganflyer about the incredible innovations of the X6

What is the main purpose of the X6?

The Draganflyer X6 was developed as a safe and easy-to-use platform to carry an aerial imaging system that provided clear high-resolution images. At the time of development, systems that could carry a high-resolution camera were generally large, dangerous and difficult to control.

What sets it apart from other drones in existence?

It has a unique design with six rotors in the Y-style configuration, as well as its ability to fly even if it is missing one of the rotors. When it was first released, the concept of using sUAS (Small Unmanned Aircraft Systems) for civilian purposes was practically unheard of, so the attention it received made it stand out from other models.

What are your hopes for the X6 in the future?

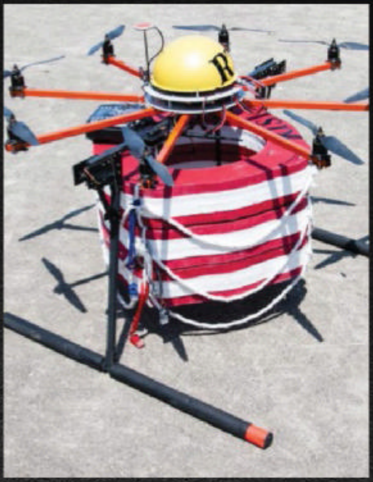
The Draganflyer X6 was our first industrial system and was responsible for setting a lot of firsts for the industry. Since then we have developed other improved systems based on our experience with the X6. Our hopes are to work some technology upgrades into its design and for it to again become a front-runner in the sUAS world.

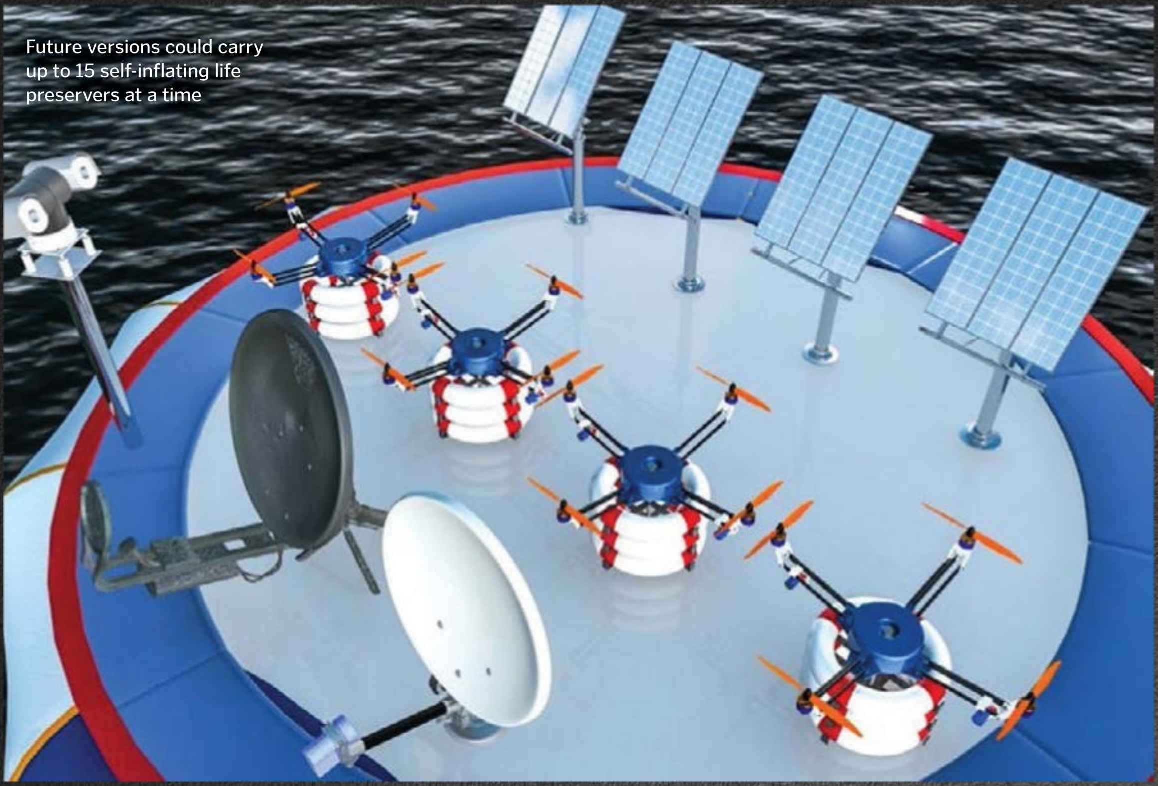
The Draganflyer X6 can carry cameras weighing 335g (11.8oz) or less, including a GoPro

LIFEGUARD DRONE

Getting help to those in trouble at sea is especially difficult and slow, particularly in adverse weather conditions. Iranian company RTS Lab hopes drones can solve this, as it is currently developing a new lifeguard robot called Pars. After hearing about the huge number of people that drown in the Caspian Sea each year, RTS Lab decided to create a multirotor drone that could help save human lives. As well as being able to fly above the water and be guided by GPS, Pars can also carry and drop life preservers to where they are needed.

Although it is not able to pull people to safety, it can provide initial aid before the lifeguard arrives and monitor the situation by recording photos and video. A prototype has already been tested, and was able to reach a target 75 metres (246 feet) out to sea in just 22 seconds, while a human lifeguard took over a minute.

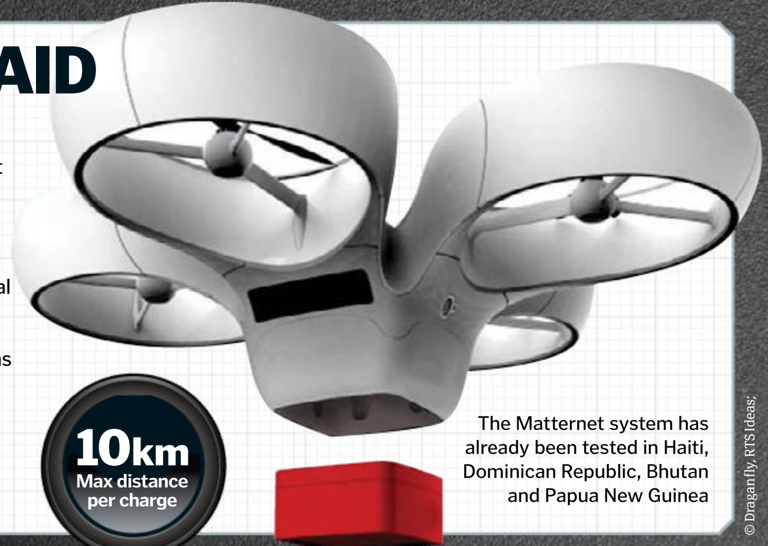




Future versions could carry up to 15 self-inflating life preservers at a time

DELIVERING AID

In many developing countries, rural roads become inaccessible during the rainy season, making it very difficult to transport much-needed medicine to those in need. Matternet – a network for transporting matter – aims to provide the solution. The plan involves autonomous drones, carrying up to two kilograms (4.4 pounds) of medical supplies, flying between several ground stations. These stations would allow the drones to collect or drop off their payload as well as swap batteries so they can keep flying for longer. The drones will use GPS and other sensors to navigate and an operating system would make sure they avoid adverse weather conditions and do not collide with each other.



10km
Max distance per charge

The Matternet system has already been tested in Haiti, Dominican Republic, Bhutan and Papua New Guinea

© Draganfly; RTS Ideas;

The Parrot AR.Drone 2.0 is controlled via an app on your Android or Apple device

COMMERCIAL USE

The drones offering film-makers a whole new perspective

Drones such as the Parrot AR and the DJI Phantom 2 Vision+ have added a thrilling new dimension to personal photography and filmmaking. These clever gadgets are becoming more and more affordable for amateurs looking to capture Hollywood-style footage from unique angles.

A Parrot AR.Drone, for example, will only set you back around £320 ($300) and has a built-in camera that can shoot 720-pixel high-definition video. It generates its own Wi-Fi hotspot so you can control it from up to 50 metres (165 feet) away via an app on your smartphone or tablet. The app also shows a live stream of the video being captured and lets you change its direction by simple tilting your device. It can even perform impressive flips in mid-air, and you can program automatic movements to compose your film like a professional director.

If you do happen to crash the drone while filming a daring action sequence, then you can have a go at repairing it yourself as all of the parts and instructions are available online. Due to the relatively recent advancement of commercial drone technology, many countries are still developing laws regarding their use in public spaces. In the United States, the Federal Aviation Administration currently limits drones to be flown below 122 metres (400 feet), away from airports and air traffic, and within sight of the operator.

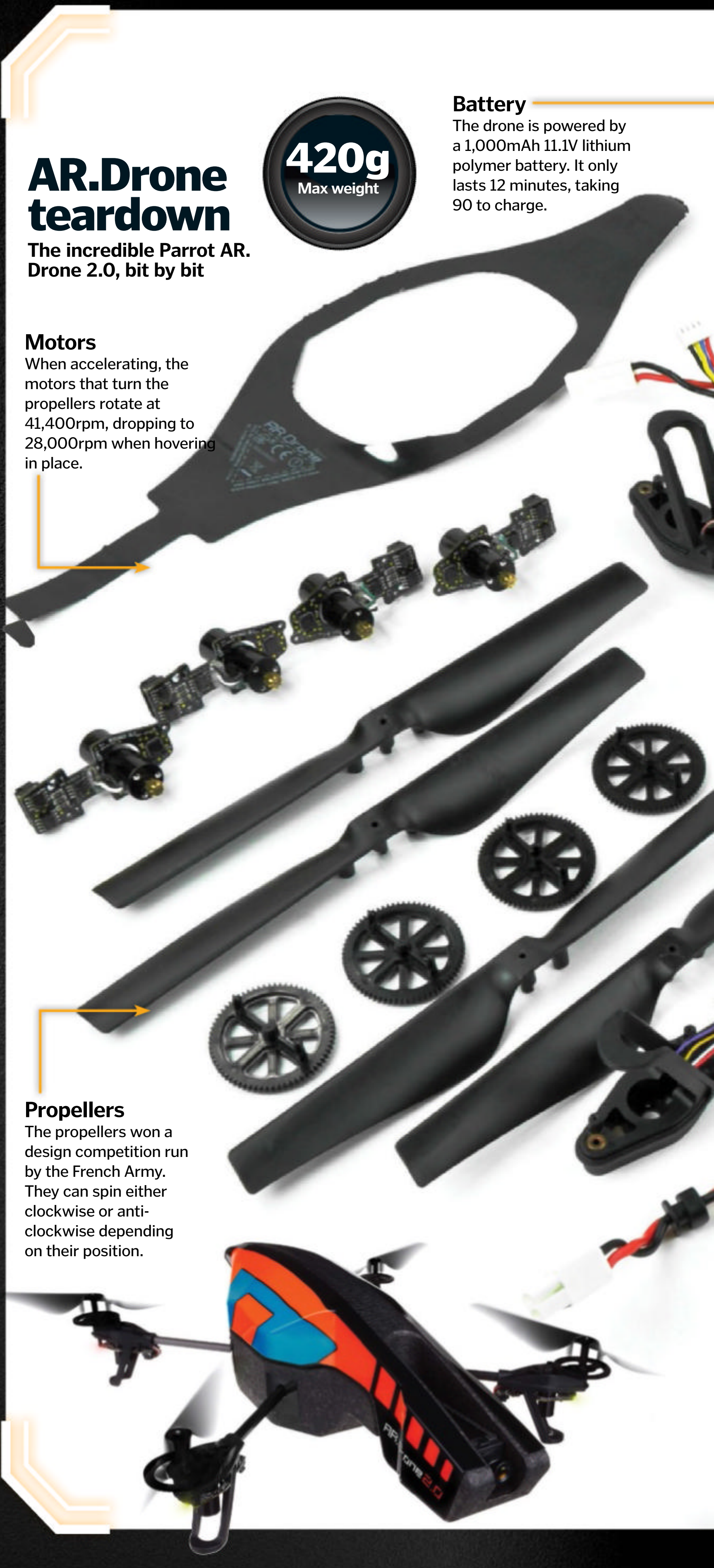
Using drones in a professional capacity requires a certificate of approval from the FAA, but it has recently granted six movie and television production companies permission to use drones on their sets. Some big blockbusters, such as *Skyfall* and the *Harry Potter* movies, have already been shot using unmanned drones for aerial footage, but filming took place in countries where this was allowed.

We are already seeing more and more drone-shot sequences on the big screen. Not only is this great news for us cinemagoers, as we will be treated to more creative camera angles, but it will also save the production companies a lot of money on helicopter and crane bills as they try to get above the action while filming.

AR.Drone teardown

The incredible Parrot AR. Drone 2.0, bit by bit

420g
Max weight

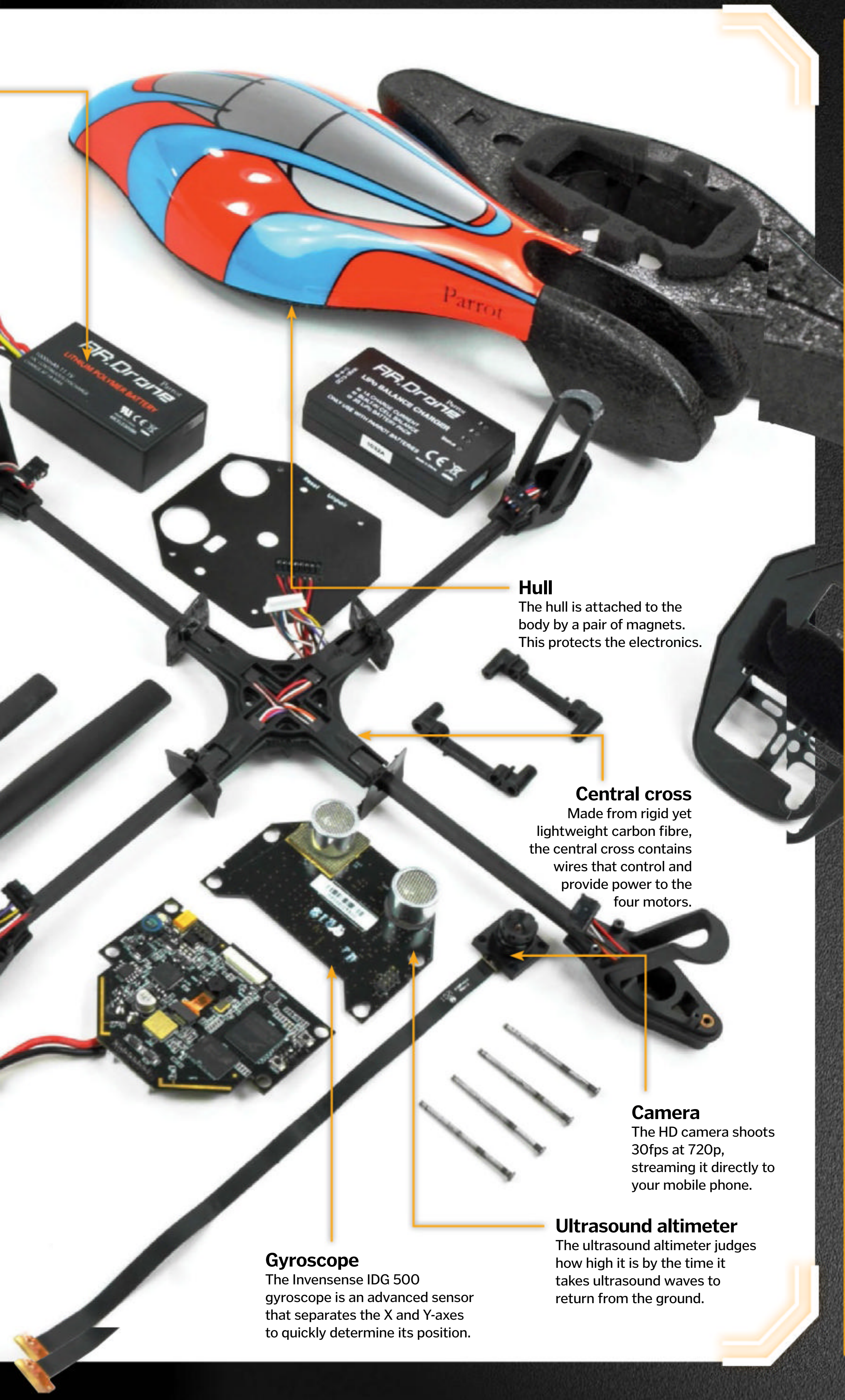


Battery
The drone is powered by a 1,000mAh 11.1V lithium polymer battery. It only lasts 12 minutes, taking 90 to charge.

Motors
When accelerating, the motors that turn the propellers rotate at 41,400rpm, dropping to 28,000rpm when hovering in place.

Propellers
The propellers won a design competition run by the French Army. They can spin either clockwise or anti-clockwise depending on their position.

DID YOU KNOW? *TV coverage of skiers and snowboarders at the 2014 Winter Olympics in Sochi was shot by unmanned drones*



Hull
The hull is attached to the body by a pair of magnets. This protects the electronics.

Central cross
Made from rigid yet lightweight carbon fibre, the central cross contains wires that control and provide power to the four motors.

Camera
The HD camera shoots 30fps at 720p, streaming it directly to your mobile phone.

Ultrasound altimeter
The ultrasound altimeter judges how high it is by the time it takes ultrasound waves to return from the ground.

Gyroscope
The Invensense IDG 500 gyroscope is an advanced sensor that separates the X and Y-axes to quickly determine its position.

BEST FOR... VIDEO STREAMING

DJI Phantom 2 Vision+
Price: £940/$1299 • **Get it from:** www.dji.com

BEST FOR... EVERYDAY FUN

Parrot MiniDrone Rolling Spider
Price: £90/$100 • **Get it from:** amazon.co.uk

BEST FOR... BEGINNERS

Walkera QR Ladybird V2
Price: £60/$89 • **Get it from:** walkera.com

BEST FOR... STUNTS

Blade 350 QX V2
Price: £340/$575 • **Get it from:** quadcopters.co.uk

BEST FOR... AFFORDABILITY

Hubsan X4 H107
Price: £45/$70 • **Get it from:** amazon.co.uk

ANIMAL PROTECTORS

Drones are revolutionising the way wildlife conservationists keep poachers at bay

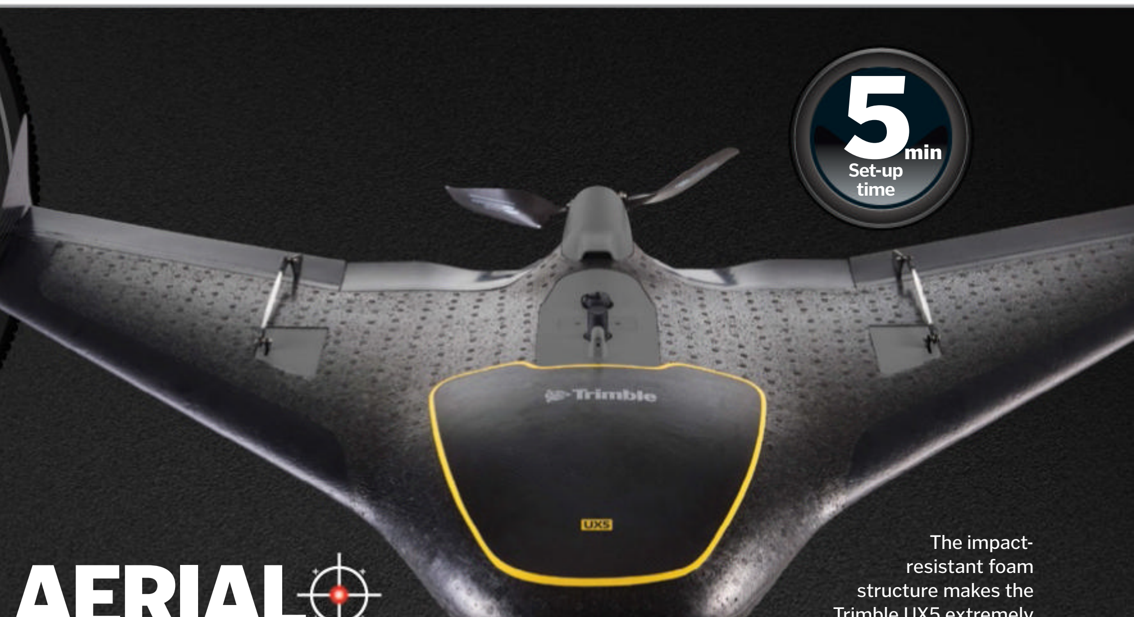
As well as helping to save the lives of humans, drones can also come to the rescue of animals in the wild. The Ol Pejeta Conservancy in Kenya is East Africa's largest black rhino sanctuary but has lost several rhinos to poachers in recent years. They have now teamed up with drone company Airware to see if unmanned aircraft can help protect this endangered species. A prototype Aerial Ranger drone, featuring a camera that can deliver real-time video and thermal imaging to a team on the ground, has been tested during the day and night to respond to poaching incidents. Ol Pejeta only has around 150 rangers, each having to cover 2.4 square kilometres (0.93 square miles) of the 364-square-kilometre (140.5-square-mile) sanctuary. This makes response times to poaching incidents very slow, but using a drone allows them to get there immediately and record footage of the offending individuals to use as evidence in court and deter further attacks. It would scare off potential future poachers at least.

The drones would also be useful for monitoring the rhino, as well as protecting them. It would allow Ol Pejeta to conduct their annual wildlife census more regularly and cheaply, helping them to reliably keep track of the ecosystem.

Microsoft has also ventured into animal-tracking drones with their ZooTracer project. It involves attaching tiny GPS tracking and sensing devices, weighing just seven grams (0.25 ounces), to animals. These devices can record all sorts of data, such as the animal's speed, and then a drone is deployed to the animal's location to get the data back and monitor the animal further.

Ol Pejeta is home to three of the six remaining northern white rhino in the world

DID YOU KNOW? *California's Casa Madrona Hotel uses drones to deliver champagne to guests in their $10,000-a-night luxury suite*



5 min
Set-up time

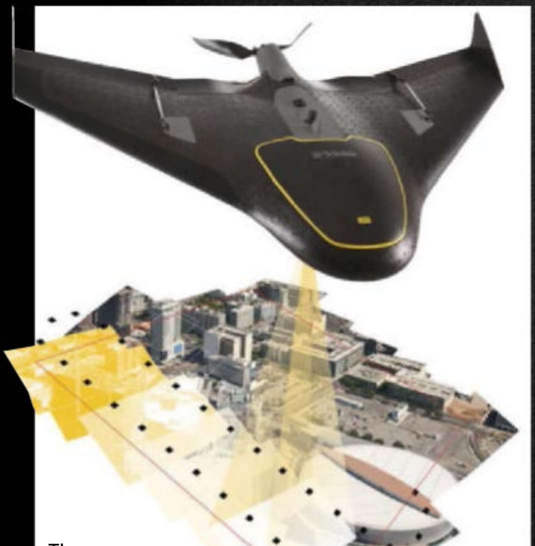
The impact-resistant foam structure makes the Trimble UX5 extremely durable and strong

AERIAL MAPPING

The drones making difficult jobs so much easier

The advancements in drone technology have been extremely beneficial for industry. From engineering and surveying to mining and agriculture, a variety of markets are embracing this new tool to improve day-to-day operations. The Trimble UX5 is one of the leading surveying and mapping drones being used by many companies. It features a 16.1-megapixel camera for taking several overlapping high-resolution images, which are then layered together by specialist image-editing software to collate a map. By taking several photos from different locations, triangulation can be used to determine accurate coordinates and create three-dimensional plans of the area free from distortion. This proves invaluable when planning new infrastructure, inspecting mines and monitoring forests, and because the drone is autonomous and unmanned, it provides a much safer, quicker and cheaper solution than the pilot-controlled alternative. Plus, it is made from expanded polypropylene, a durable material that enables it to fly in practically any weather and even float on water.

The Trimble UX5 takes off from an angled launcher that helps it safely clear the ground and climb into the air, where it then flies a preplanned route travelling back and forth over the area. An application on the Trimble Tablet Rugged PC is used to plan flights and operate the drone easily and reliably, but once in the air it uses GPS to navigate. When its flight is over, the drone automatically begins its landing sequence, circling above a preplanned landing spot and using reverse thrust to help it land in tight spaces.



The Trimble UX5 can be used for mapping projects

DELIVERY DRONES

Although commercial drones are mainly being used by specialist industries, consumer companies certainly haven't failed to notice their potential. In the not-so-distant future, the skies above us could be swamped with a network of drones delivering our shopping, or even fast food, straight to our front door. Many big companies are testing this new delivery method, but it is likely to be several years before the idea becomes reality. Many countries, including the United States, do not allow drones to be flown at low altitude over residential areas, and the autonomous aircraft currently have no way of avoiding obstacles en route.

amazon PrimeAir

Amazon Prime Air

Amazon is already developing and testing drones for delivering packages weighing up to 2.3 kilograms (five pounds) to customers within 30 minutes of ordering. The retail giant is just waiting for permission from the FAA before it can roll out the new system, which is expected to happen in 2015.

DHL parcelcopter

Logistics firm DHL is the first company to launch a drone-based delivery service. Its 'parcelcopter' is currently being used to deliver small parcels to the German island of Juist in the North Sea. A restricted flight area has been established for the service, which mainly delivers medication and other urgently needed goods.

Burrito Bomber

The Burrito Bomber is a Mexican food-delivery system that lets you place your order via an app. A drone will then fly to your location and parachute your snack down to you in a custom-made Burrito Delivery Tube. It should be up and running – in the US, at least – once the FAA updates its regulations.

© DHL; Amazon; Trimble; Draganfly; RTS Ideas;

REAL-LIFE BOND CARS

REVEALED: THE GADGET-PACKED, BULLETPROOF RIDES THAT SHIELD SPIES, ROYALS AND WORLD LEADERS

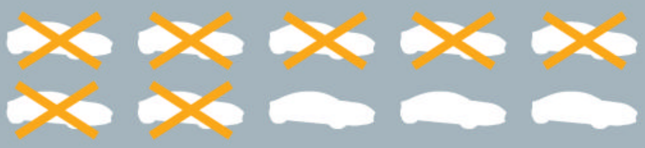
Flamethrowers
The only DB10 gadget revealed so far is a set of powerful flamethrowers that shoot fire from the rear of the car.

Manual transmission
Bond will have to shift gear himself as the car features a six-speed manual transmission unit instead of an automatic gearbox.

> *"Aston Martin worked closely with the movie's director to design the DB10"*

Not for sale

Aston Martin have only made ten of the cars, and all of them have been used on the set of the movie. Seven were written off in destructive stunts!



DID YOU KNOW? *Casino Royale's Aston Martin performed seven barrel rolls assisted by an air cannon, breaking the world record*

007's new wheels

Meet Bond's sleek and speedy co-star from the latest movie, Spectre

Whether he's chasing down villains or wooing Bond girls, 007's most important gadget is always his car. The new movie is no exception, and will pit the Aston Martin DB10 against the powerful Jaguar C-X75 concept car in an extreme cat-and-mouse chase around the streets of Rome. Aston Martin worked closely with the movie's director Sam Mendes to design Bond's bespoke DB10, but has adopted MI6-level secrecy about the car's features. In the movie trailer, Bond's gadget inventor, Q, says that the two-door coupe has "a few little tricks up her sleeve", but only a few of these have been revealed. Here's what we know so far…

Aston Martin DB10

The state-of-the-art features, for your eyes only

Up to speed
In the *Spectre* trailer, Q reveals that the DB10 can go from 0-97km/h (0-60mph) in 3.2 seconds.

Under the hood
The car's inner workings are based on those of the V8 Vantage, including its 4.7-litre (1.2-gallon) V8 engine.

James Bond's high-octane adventures showcase cutting-edge car tech

The new James Bond film *Spectre* sees the world's favourite spy reunited on-screen with his most beloved car brand, the Aston Martin. But of course Bond doesn't drive just any old Aston Martin. The suave secret agent has a long and colourful history of being handed the keys to the most tricked-out, gadget-stuffed ride on the planet – right before he goes and ruins it. But this is all just fiction, right?

Actually: wrong. A growing number of jittery celebrities – including ex-Spice Girl Mel B and rapper Kanye West – have been investing in armoured vehicles, many of them bristling with features like electric shocking door handles, aimed to deter paparazzi and would-be carjackers. From the outside, these vehicles are indistinguishable from the standard models, but to their occupants they are four-wheeled fortresses that lend them peace of mind as they travel from A to B.

US firm Texas Armoring Corporation (TAC) outfits as many as 100 such "personal protection" vehicles per year. According to CEO Trent Kimball, though, paranoid actors, musicians and sports stars make up only a small minority of the company's clientele. Instead, most of their vehicle upgrades are performed for what Kimball terms "high net worth individuals" travelling in places where there is a very real, very serious kidnap-for-ransom risk. ▶

THE BEST BOND CAR GADGETS

Ejector seat

In *Goldfinger*, Bond's Aston Martin DB5 is equipped with an ejector seat for swiftly removing any unwanted passengers. The car also has built-in machine guns, tyre spikes and can create a smokescreen to help fend off the enemy.

Rocket boosters

The Aston Martin V8 Vantage Volante's normal engine isn't powerful enough for 007 in *The Living Daylights*, so his is kitted out with a rocket propulsion system. The armrest also has a built in control panel for operating lasers and missiles.

Invisibility cloak

In *Die Another Day*, 007 can evade detection by simply activating the adaptive camouflage of his Aston Martin V12 Vanquish, making it disappear completely. He can then deploy the missiles mounted in the front grille to defeat the bad guys.

Submarine car

007 can navigate land and sea with his Lotus Esprit S1 in *The Spy Who Loved Me*. It swiftly transforms into a submarine when Bond drives it off the end of the pier, then becomes a car again when he reaches the beach.

Remote control

Bond can control his BMW 750iL with his Ericsson mobile phone in *Tomorrow Never Dies*, so he doesn't even need to be behind the wheel. It also has bulletproof windows and electrified door handles to shock any thieves.

Defibrillator

When Bond drinks a Martini spiked with poison in *Casino Royale*, he heads back to his Aston Martin DBS V12 to use its built-in defibrillator machine. A quick shock to the chest helps bring his heart rate back to normal again.

© Thinkstock; Dreamstime; Rex Features

In countries like Nigeria, Cambodia, Venezuela, Honduras, Mexico, Saudi Arabia and Oman, kidnap-for-ransom is an everyday occurrence, explains Kimball. For wealthy business people, entrepreneurs and mid-level executives, investing around $80,000 (approx £53,000) to armour a vehicle that will keep themselves and their families safe not only spares them the emotional turmoil that such an attack would involve – it makes financial sense too.

For these clients, keeping a low profile is paramount; they're keen not to draw attention to themselves with bulky, flashy autos that advertise their status. That's why TAC armours its cars from the inside out, leaving the classic shell of the vehicle in tact, with little hint of its inner strength. "These tend to be luxury vehicles," explains Kimball, "and we want to make sure we put them back as close to the original as possible."

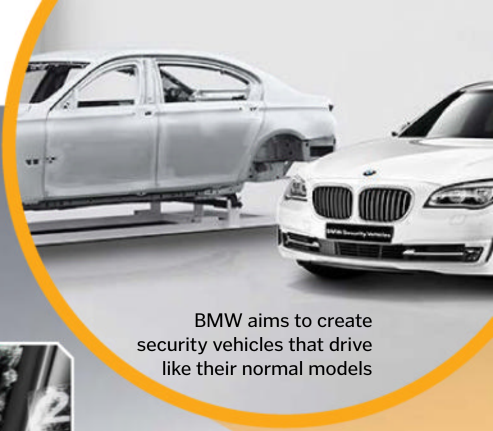
The entire frame of the car is reinforced with cutting-edge materials, including high-hardened ballistic steel, Kevlar, aramid fibres and polyethylene, while the windows are replaced with bulletproof glass. By the time the TAC team is finished, the vehicle is bombproof.

Kimball is so confident in the materials the company uses that he once got behind the wheel of one of their outfitted cars, had an employee aim an AK-47 at his head and instructed them to discharge a round of bullets. Video evidence on YouTube shows Kimball didn't so much as flinch as the bullets cracked lacy patterns into the top surface of the bulletproof glass. James Bond, eat your heart out.

But all that armouring comes at more than just financial cost. There are performance trade-offs as the added weight affects the way the vehicle handles and responds. "Ultimately I need a vehicle that I can turn, that I can stop, that I can do things to manoeuvre out of a kill zone," points out secure transportation expert Joe Autera, who spent over a decade driving high profile clients in some of the most dangerous locations on Earth, and now trains others to do the same. ▶

BMW X5 Security Plus

The first vehicle specifically designed to protect against the world's most widely used firearm, the AK-47



BMW aims to create security vehicles that drive like their normal models

2
3
1
219
218
222
221
26
25

Bullet-resistant glass

Laminate security glass with a polycarbonate coating protects occupants from bullets and glass shrapnel.

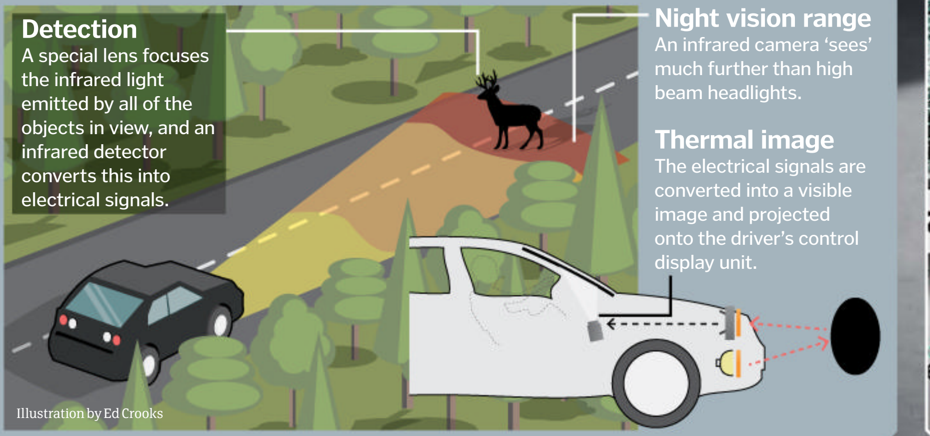
BMW X5 Security
292
293
294
295
301
302

Safety features

The car boasts run-flat tyres, a self-sealing fuel tank, and an attack alarm and intercom system that lets occupants communicate with the outside world without leaving the safety of the vehicle.

How infrared cameras work

Infrared cameras like the BMW Night Vision system allow drivers to perceive their surroundings even in pitch-black darkness. Instead of visible light, which our eyes are built to detect, they 'see' the infrared part of the electromagnetic spectrum. As living things give out heat in this portion of the spectrum, the camera can pick out occupied vehicles and potential human threats.



Detection

A special lens focuses the infrared light emitted by all of the objects in view, and an infrared detector converts this into electrical signals.

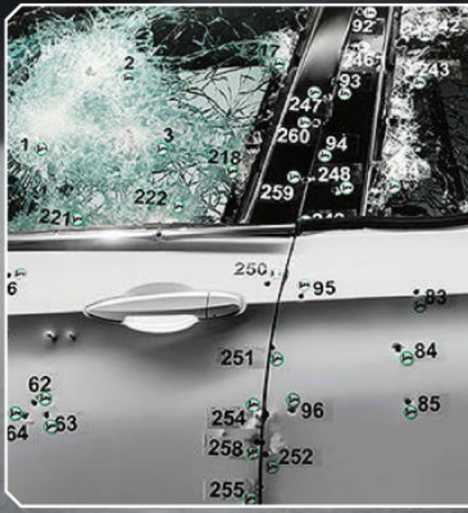
Night vision range

An infrared camera 'sees' much further than high beam headlights.

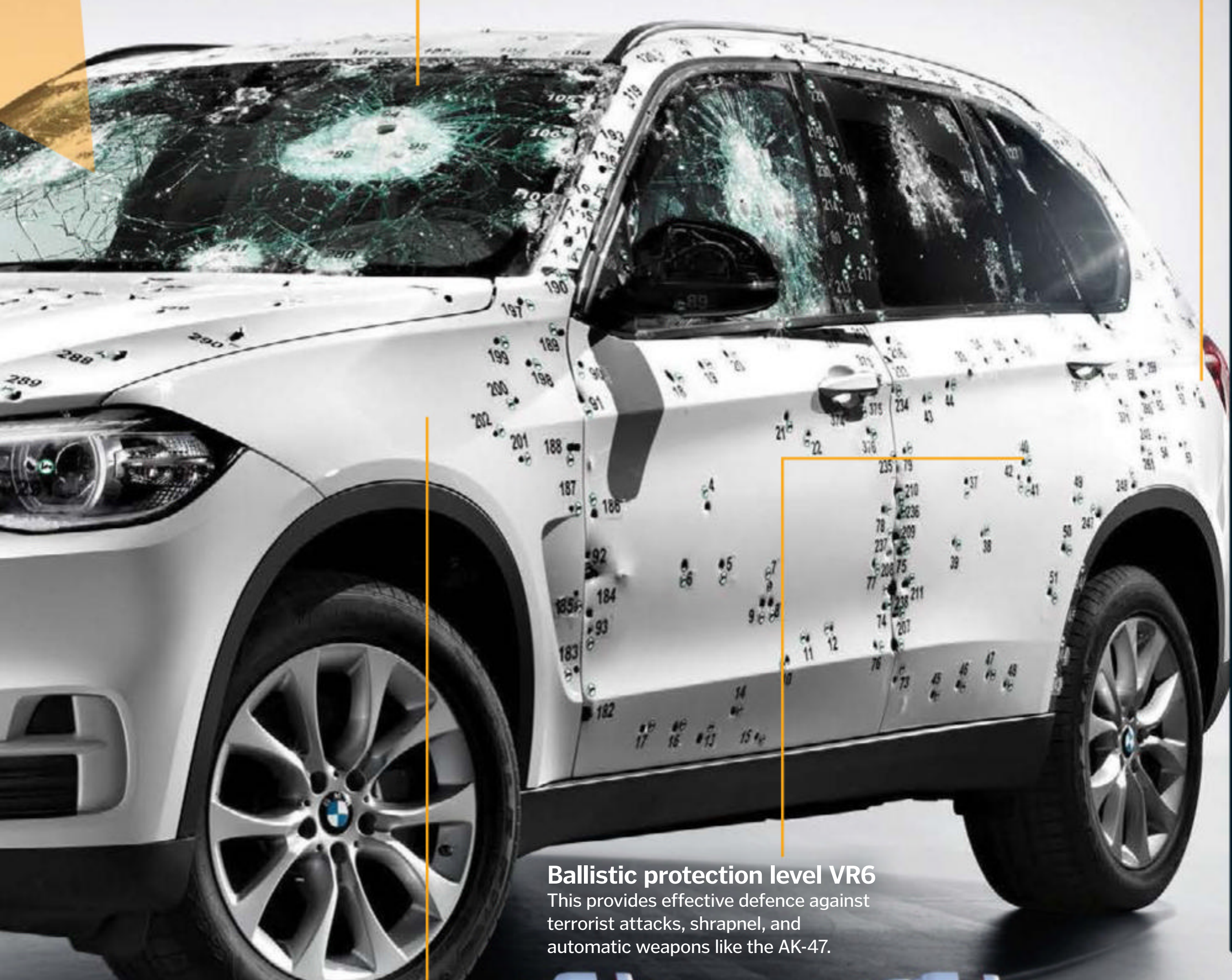
Thermal image

The electrical signals are converted into a visible image and projected onto the driver's control display unit.

Illustration by Ed Crooks



DID YOU KNOW? *The most popular armoured vehicles on the market today are the Toyota Land Cruiser and the Lexus LX570*



Interior
Inside, the car is fully equipped with BMW's renowned luxury features and finishing.

BMW xDrive
An all-wheel drive system adapts to all surfaces and conditions, redistributing power between the front and rear axles accordingly for maximum traction and control.

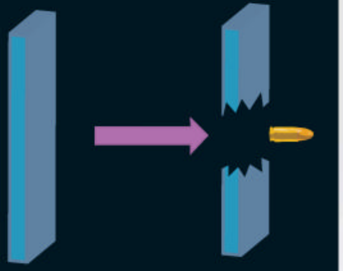
Ballistic protection level VR6
This provides effective defence against terrorist attacks, shrapnel, and automatic weapons like the AK-47.

Armour
Passenger cell protected by a steel armour sheath; aramid and polyethylene sealed joints provide protection where body panels meet.

How bulletproof glass works

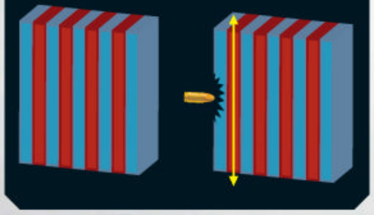
Ordinary glass

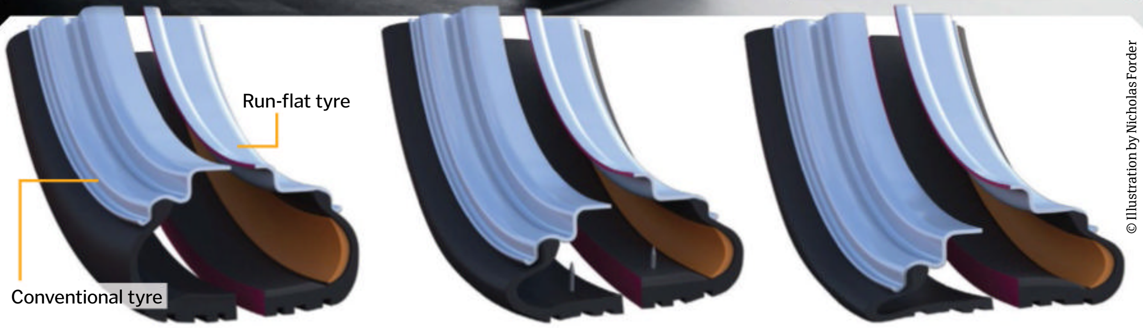
Glass is brittle, meaning that it fractures easily when subjected to stress. When a bullet strikes it, glass can't bend to absorb the energy gradually (in the way you might track your hand back when catching a fast-moving ball). Instead, it shatters, allowing the bullet to pass straight through with almost no loss of momentum.



Bulletproof glass

Technically 'bullet-resistant', since no glass is 100 per cent bulletproof, this material is made by sandwiching layers of an elastic polycarbonate plastic (red) between sheets of toughened glass (blue). When a bullet hits, the outer glass layers still break but the plastic stops them from flying apart. The bullet's energy is dissipated sideways through the multiple layers, which quickly brings it to a stop.





© Illustration by Nicholas Forder

How run-flat tyres work

1 Everyday use

Under normal conditions, both conventional and run-flat tyres maintain constant air pressure, providing a flexible cushion that absorbs shock and increases traction between the vehicle and road.

2 Puncture

After a puncture, conventional tyres drop in pressure immediately. Run-flat tyres have a reinforced sidewall that helps the tyre maintain its shape and stops the wheel rim making contact with the road.

3 Post-puncture

Even when completely depressurised, run-flat tyres can hold out for around 80 kilometres (50 miles), preventing drivers from losing control of their vehicle and allowing them and their cargo to escape danger.

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Official state cars

The high-security vehicles that protect world leaders and royalty

The PM's jacked-up Jag

UK Prime Minister David Cameron is chauffeured to and from engagements in a modified Jaguar XJ Sentinel, driven by a Specialist Protection officer from the Metropolitan Police Service. Bombproof doors, steel and Kevlar armouring, bulletproof glass and a grenade-proof floor keep him safe; the elegant leather and wood veneer interior keeps him feeling suave.

The prime ministerial car is escorted by a fleet of unmarked Range Rovers

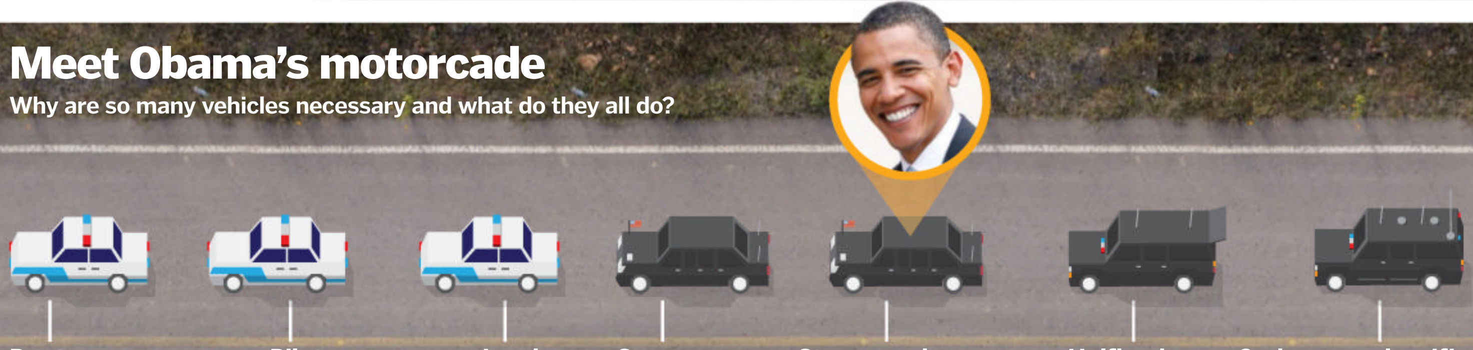
Her Majesty's motorcar

On state occasions, HRH Queen Elizabeth II travels in one of her two bespoke Bentley State Limousines. Gifted to her in 2002 to commemorate her Golden Jubilee, these heavily armoured carriages feature rear-hinged doors for elegant entry and exit, and removable panelling to customise the visibility of their occupants.

The Queen and her head chauffeur had an input on the design of the Bentleys

Meet Obama's motorcade

Why are so many vehicles necessary and what do they all do?



Route car
A local police car sweeps about five minutes ahead of the motorcade, ensuring the route is clear.

Pilot car
Another car runs a minute ahead of the motorcade, validating that the route is clear.

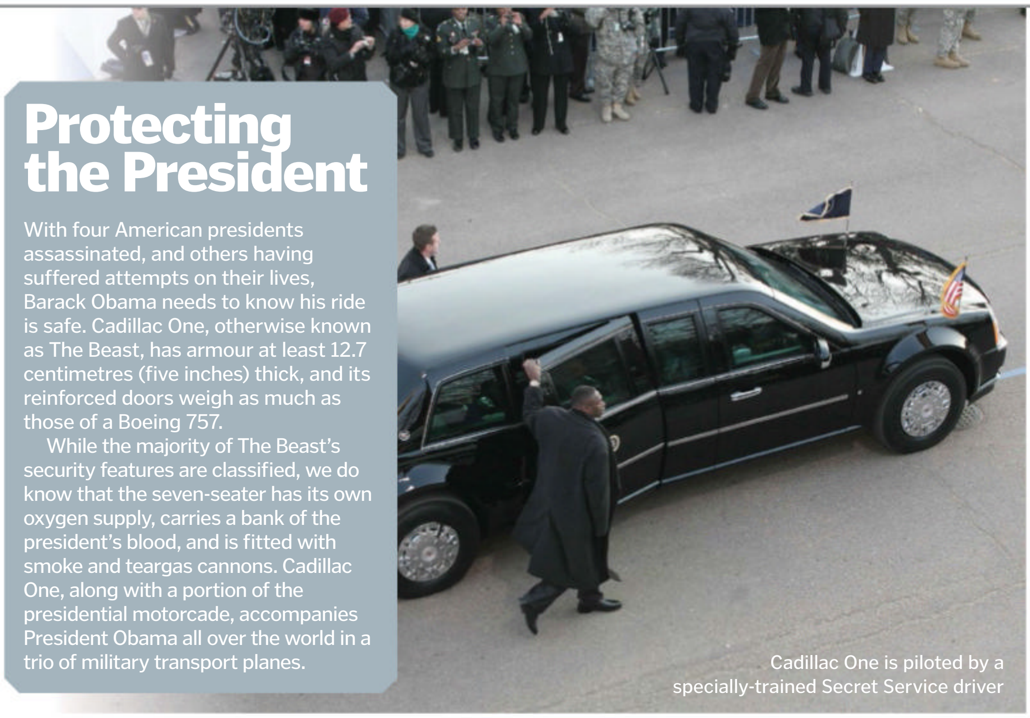
Lead car
A marked police car guides the motorcade.

Spare
This is a decoy vehicle identical to the one the president rides in.

Stagecoach
The president officially rides in this vehicle, although in reality he could be hidden anywhere in the motorcade.

Halfback
This SUV carries the president's Secret Service protection detail.

Codename classified 1
An electronic countermeasures vehicle detects improvised explosive devices or incoming missiles, and sends out jamming signals.



Protecting the President

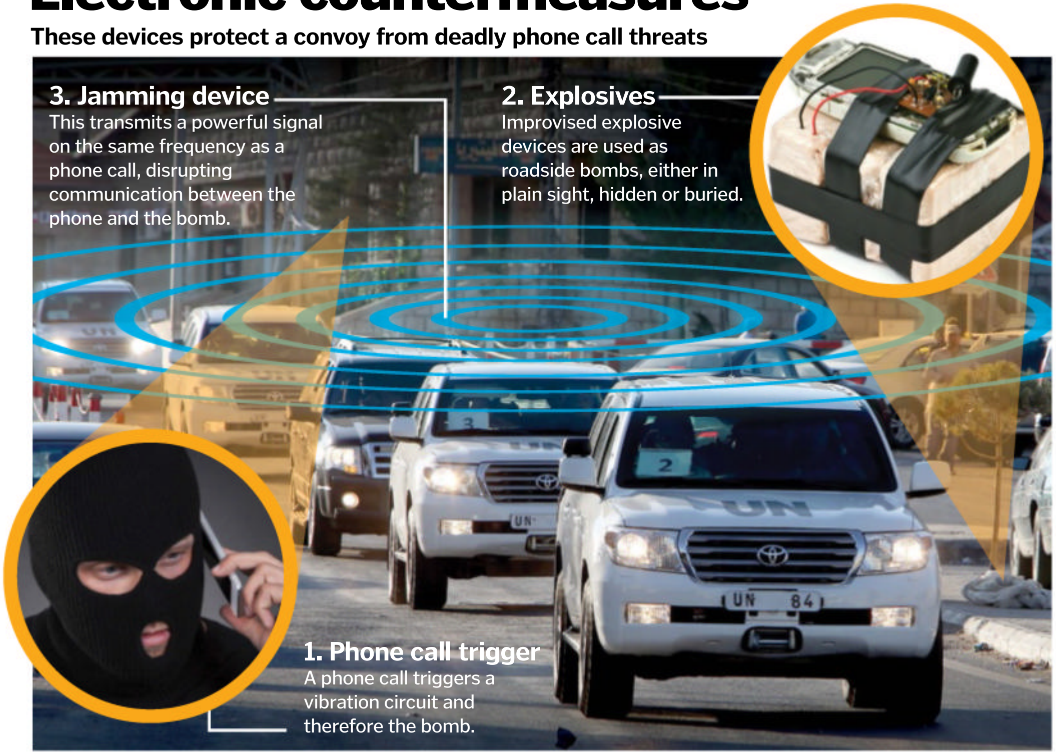
With four American presidents assassinated, and others having suffered attempts on their lives, Barack Obama needs to know his ride is safe. Cadillac One, otherwise known as The Beast, has armour at least 12.7 centimetres (five inches) thick, and its reinforced doors weigh as much as those of a Boeing 757.

While the majority of The Beast's security features are classified, we do know that the seven-seater has its own oxygen supply, carries a bank of the president's blood, and is fitted with smoke and teargas cannons. Cadillac One, along with a portion of the presidential motorcade, accompanies President Obama all over the world in a trio of military transport planes.

Cadillac One is piloted by a specially-trained Secret Service driver

Electronic countermeasures

These devices protect a convoy from deadly phone call threats



3. Jamming device
This transmits a powerful signal on the same frequency as a phone call, disrupting communication between the phone and the bomb.

2. Explosives
Improvised explosive devices are used as roadside bombs, either in plain sight, hidden or buried.

1. Phone call trigger
A phone call triggers a vibration circuit and therefore the bomb.

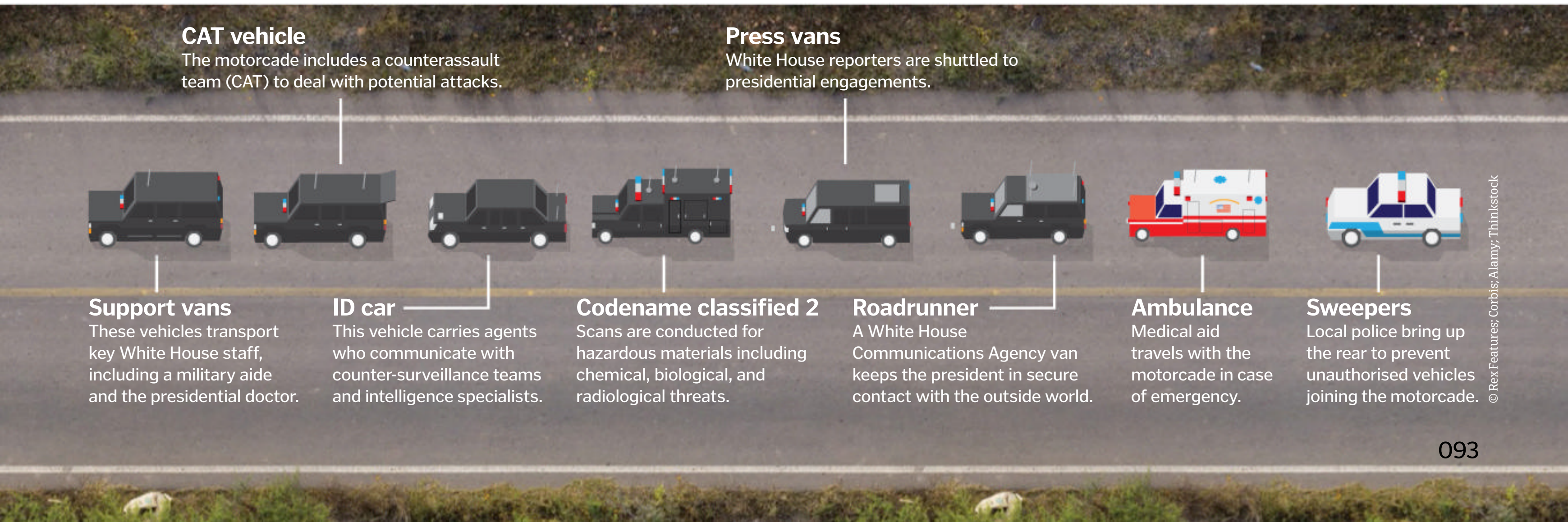
▶ Autera pegs TAC's vehicles as some of the best in the business because they use the lightest weight ballistic steel on the market and strive to find a good balance between extreme armouring and preserving high-end vehicles' original capabilities.

"The armour is only going to be used once in the vehicle's lifetime," explains Kimball, "but the vehicle is used daily, so you want it to perform like a regular vehicle." To ensure that's the case, TAC replaces components of the braking and suspension systems with meatier versions, and reprogrammes the vehicle's computer to eke out the best performance under the new weight conditions.

Nevertheless, armoured vehicles handle differently to their conventional counterparts, making specialised driver training essential. Autera schools private sector, government, military and law enforcement personnel in evasive driving, vehicle counter-ambush and counter-carjacking techniques, and offensive driving. "An essential part of protecting someone in a high-risk environment is an armoured vehicle," he says.

And Autera should know. "We were attacked by a group that was trying to stop our motorcade and either kidnap or assassinate the principal," he recalls of one incident during his time as a driver. "They tried to block our path and they engaged the vehicles with AK-47s. We were able to evade the blocking vehicle and, because we were in armoured vehicles, even though our vehicles took fire, none of the rounds penetrated."

Confidence and composure are critical in such high-stake situations. "You can't inoculate somebody against the response to stress," Autera explains. But training helps drivers to recognise the effects of extreme adrenaline – the narrowing field of vision, muffled hearing, and loss of motor skills – and overcome these to take the necessary actions to move their vehicle and passengers out of danger. "That confidence is essential to survival," he says, "because an armoured vehicle simply buys you time." ▶



CAT vehicle
The motorcade includes a counterassault team (CAT) to deal with potential attacks.

Press vans
White House reporters are shuttled to presidential engagements.

Support vans
These vehicles transport key White House staff, including a military aide and the presidential doctor.

ID car
This vehicle carries agents who communicate with counter-surveillance teams and intelligence specialists.

Codename classified 2
Scans are conducted for hazardous materials including chemical, biological, and radiological threats.

Roadrunner
A White House Communications Agency van keeps the president in secure contact with the outside world.

Ambulance
Medical aid travels with the motorcade in case of emergency.

Sweepers
Local police bring up the rear to prevent unauthorised vehicles joining the motorcade.

© Rex Features; Corbis; Alamy; Thinkstock

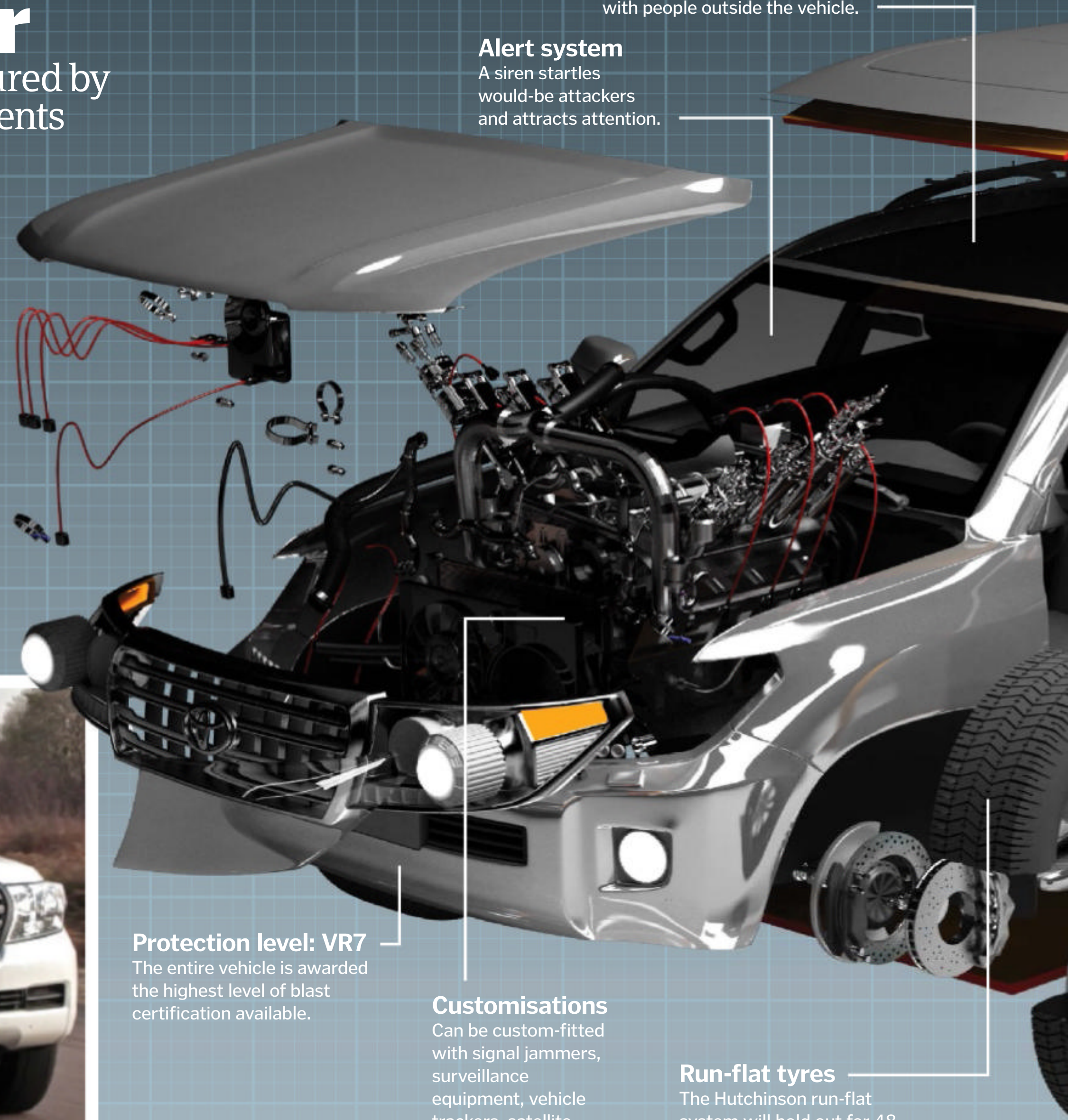
Inside the Jankel Land Cruiser

The armoured SUV 200 favoured by military, NGOs and governments

Industry leader Jankel produces armoured vehicles for police, international security forces and military clients worldwide. Their armoured Toyota Land Cruiser 200 offers extreme blast protection that makes it popular with humanitarian and security organisations operating in hostile environments like warzones.

Its armour is hot-formed, meaning it is heat-moulded to the vehicle from just 31 individual pressed panels (as opposed to the hundreds of pieces used in conventional armouring approaches). This kind of armouring is quicker to complete and the finished product is cheaper, lighter, and more protective than any other alternative.

The entire vehicle goes through extensive live-fire and blast testing, including ballistic rounds fired, hand grenades detonated on its roof, mines detonated under the seats, and 15 kilograms (33 pounds) of TNT detonated two metres (6.6 feet) from the side door. Its performance in these tests earns it a protection certification at one of the highest levels available: VR7.



Secure communication
A PA and intercom system allows occupants to communicate securely with people outside the vehicle.

Alert system
A siren startles would-be attackers and attracts attention.

Protection level: VR7
The entire vehicle is awarded the highest level of blast certification available.

Customisations
Can be custom-fitted with signal jammers, surveillance equipment, vehicle trackers, satellite phones and more.

Run-flat tyres
The Hutchinson run-flat system will hold out for 48 kilometres (30 miles).

Hot-formed armour reduces welding and bolting by 70 per cent

How Texas Armouring Corporation equips their vehicles

1 Gutting

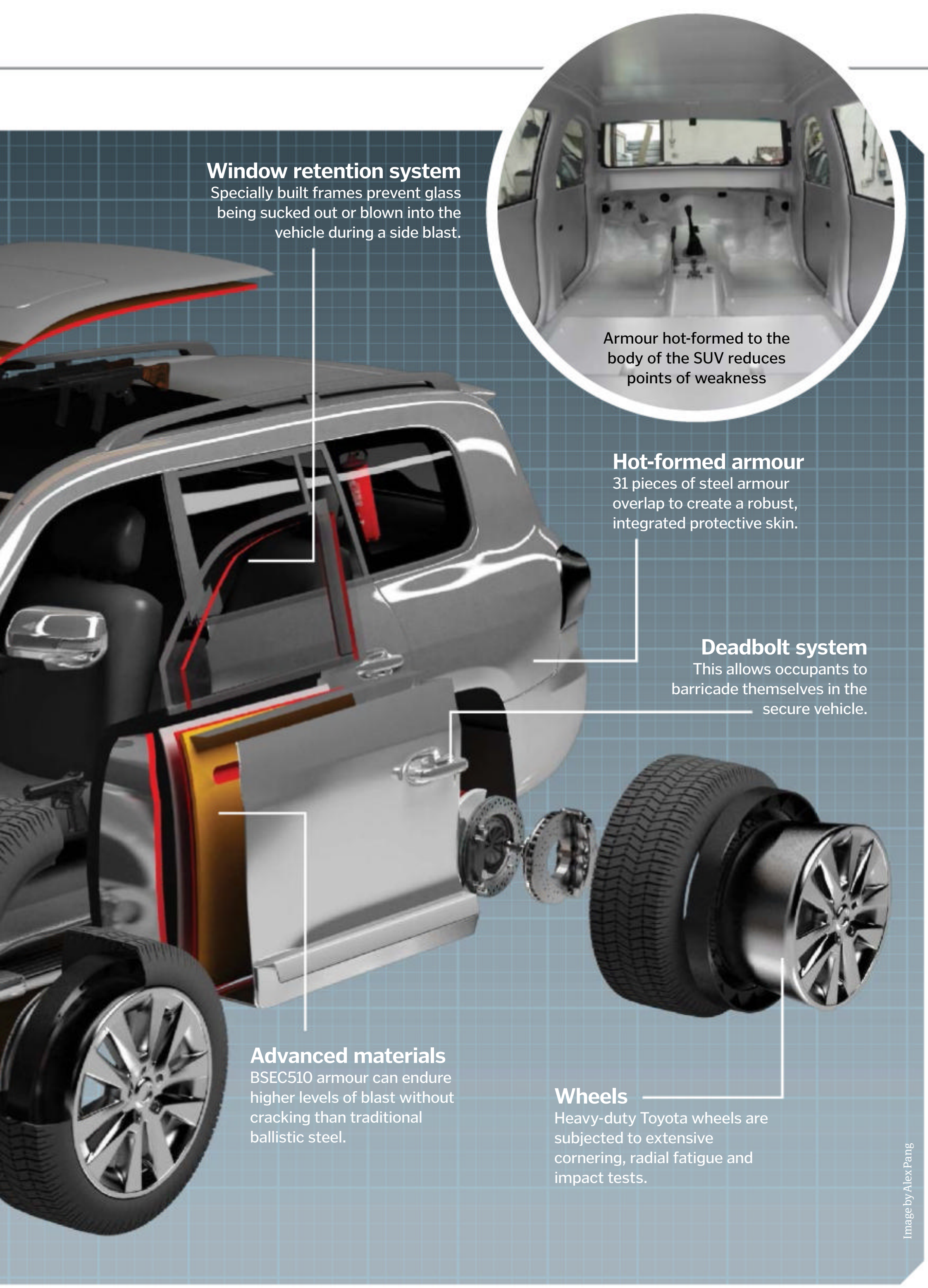
The vehicle is completely stripped. Everything on the inside – seats, floor, roof, carpet, headliners and dashboard – is ripped out, until the vehicle becomes no more than a frame. It is then readyto be lined with armoured materials.

2 Opaque armouring

The body of the vehicle – including doors, floor, roof, fire wall and pillar posts – is lined with advanced protective materials including lightweight composite armour, high-hardened ballistic steel, Kevlar and aramid fibres, and ballistic nylon.

3 Transparent armouring

The windshield, back glass, and door glass are all replaced with five-centimetre (two-inch) thick bulletproof glass. As it is so deep, everything surrounding these windows must be modified to allow the glass to fit.



Armour hot-formed to the body of the SUV reduces points of weakness

Window retention system
Specially built frames prevent glass being sucked out or blown into the vehicle during a side blast.

Hot-formed armour
31 pieces of steel armour overlap to create a robust, integrated protective skin.

Deadbolt system
This allows occupants to barricade themselves in the secure vehicle.

Advanced materials
BSEC510 armour can endure higher levels of blast without cracking than traditional ballistic steel.

Wheels
Heavy-duty Toyota wheels are subjected to extensive cornering, radial fatigue and impact tests.

Image by Alex Pang

This is where those electric shocking door handles come in. "We just want them to be able to get out of a situation, to give them any time they need," stresses Kimball. Unlike the armouring, he sees this sort of addition as an accessory. "That type of thing is fun to talk about, but it's not the life-saving technology," he explains, adding that often clients request things they've seen in Hollywood movies.

Other features that might just buy would-be victims a few extra moments to escape danger include a blinding smokescreen that can be belched out of the back of the car if someone fears they're being followed, and a road tack dispenser that drops spikes onto the road to lacerate the tyres of pursuing vehicles.

Of course, there are more serious additions too. Run-flat tyres – which use either reinforced tyre walls or hardened plastic inserts – can hold out for about 80 kilometres (50 miles) after tyres have been shot, and give a driver the chance to put some solid distance between themselves and their adversaries. A secure deadbolt locking system overrides the automatic lock release that usually happens when a car gets hit – a feature that professional kidnappers have previously been known to exploit.

Finally, internal parts like the fuel tank are also armoured – but not for the reason you might think. "A lot of times in the movies, they shoot at your fuel tank and it automatically explodes. That just doesn't happen," laughs Kimball. Fuel won't catch fire in the absence of a spark, but enough well placed shots could cause a problematic leak and affect getaway capabilities. Self-sealing foam ensures that this doesn't happen.

"Life is valuable. Protect it," runs the TAC slogan. While they may not yet be able to boast invisibility-cloaking devices – like Mr Bond's in *Die Another Day* – these fully loaded security vehicles give ordinary people priceless peace of mind in areas where the threat of armed violence is ever present.

4 Suspension and braking upgrade
Since added armour can weigh anything from 500 to 750 kilograms (1,100 to 1,650 pounds), the vehicle must be fitted with stiffer suspension springs and more heavy-duty shocks. Brake rotors and pads are replaced with racing car parts, to allow faster stopping.

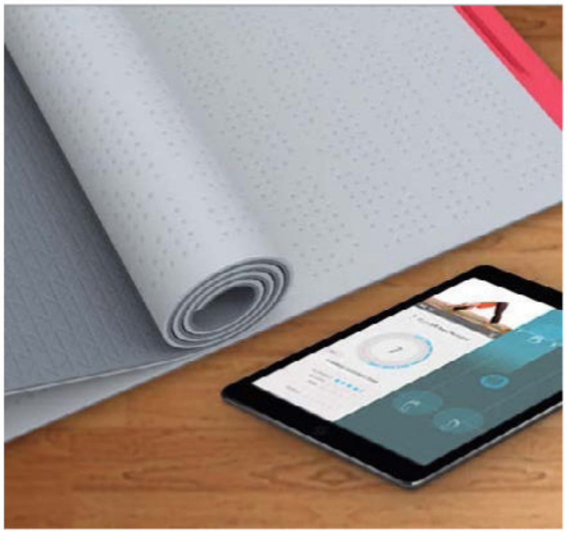
5 Parts and accessories
The fuel tank, radiator, and computer modules are fitted with armour, run-flat tyres are installed and if the client requested operable windows, the motors for these are installed, as well as any extras like a smokescreen system, road tack dispensers, or shocking door handles.

LIGHTWEIGHT ARMOR
10229

6 Interior re-install
Workers in the 'trim shop' reshape the original interior to fit the new dimensions and contours of the armoured vehicle, endeavouring to match it as closely as possible to the original, unless the client has requested custom colours, fabrics or seating configurations.

FITNESS TECH

How wearables track movement, monitor your heart rate and more



In our technology-saturated society, it's often said we're getting lazier and unhealthier. As it turns out, technology may yet save us from our screen-obsessed selves. Until recently, 'health and fitness tech' generally referred either to gym equipment built to address specific training needs, or to futuristic fabrics designed to improve our comfort (and reduce smelliness!) when engaging in athletic pursuits. That industry still booms today but, more and more, health and fitness tech has come to mean that ever-expanding collection of gadgets and gizmos that help us to dig deeper into our personal fitness data.

Welcome to the 'quantified self' movement. It's the idea that wearable activity trackers and partner apps that log every conceivable aspect of our daily lives – what we eat, how active we are, how well we sleep, and more – might helps us to understand our bodies and ourselves better and be empowered to make choices that improve our health and happiness.

Research shows that habit monitoring is one of the best ways to stick to health goals. But as mere mortals, we're pretty awful at estimating things like how far we've walked and truthfully recalling everything we've eaten in a given day! Today's fitness gadgets quietly log our health metrics and behaviours as we go about our lives, allowing us to study the numbers later and pinpoint areas that need attention.

Not only that, many of the latest products can actually suggest improvements themselves, coaching you on your positioning and technique in sports from football to yoga; making suggestions for how you might get a more restorative night's sleep; or giving you a discreet nudge when you're falling behind on your daily steps target. Elsewhere, social features of fitness apps allow peers to challenge one another, trade recipes and high fives, and offer encouragement. Never has the term healthy competition been more apt.

In the future, we'll likely see even more of these kind of functionalities integrated into our everyday smart devices, as well as our everyday lives; the American Medical Association is in favour of including smart fitness devices in a new model of preventative health care. Today we are the masters of our own fitness destiny like never before. Motivation? There's an app for that!

DID YOU KNOW? *AmpStrip, a wearable activity monitor that sticks to the skin like a plaster, was mostly crowdfunded*

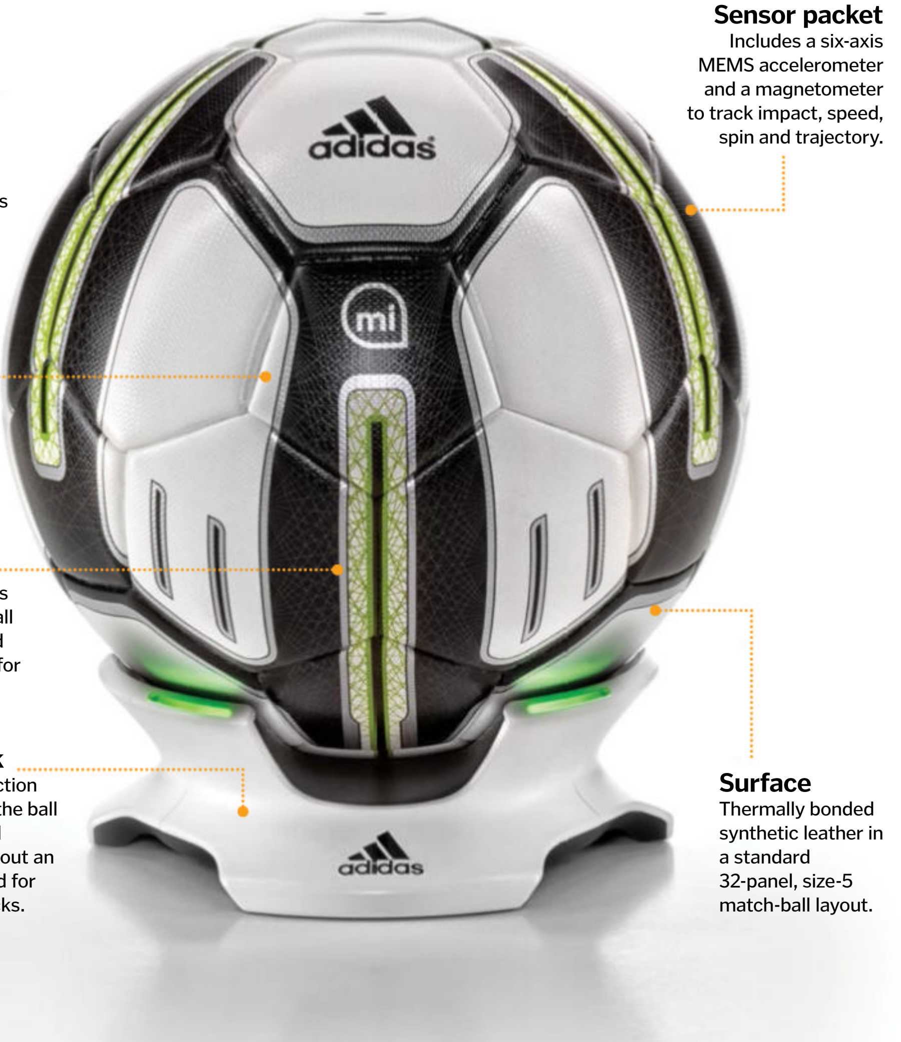
Smart football

Up your game with the ball that coaches you itself

It's the world's first football to offer feedback on your form. The Adidas miCoach Smart Ball looks, feels and handles just like any other top-of-the-line match ball, but it has one huge difference: a 'pit' of sensors suspended at its core records the strike point, speed, spin and trajectory of the ball during dead-ball drills such as penalties and free kicks.

Details of each kick are transmitted in real-time via Bluetooth, to the accompanying iOS miCoach app, which offers tips for how to correct or improve it. The app's library of drill videos makes the ball the ultimate training tool for perfecting tricky techniques – whether that be bending the ball like Beckham or knuckling it like Ronaldo.

SMART BALL Power Challenge
target range (mph)
50-60
Tomlinson wins!
Smith
Tomlinson
41mph
55mph
53mph
48mph
47mph
48mph
54mph
58mph
51mph
51mph
www.micoach.com/smartball



Shock-absorbing rods
These press against the ball's inner bladder to keep the sensor package central during impacts.

Sensor packet
Includes a six-axis MEMS accelerometer and a magnetometer to track impact, speed, spin and trajectory.

Graphics
The design helps users line the ball up correctly and acts as targets for different kicks.

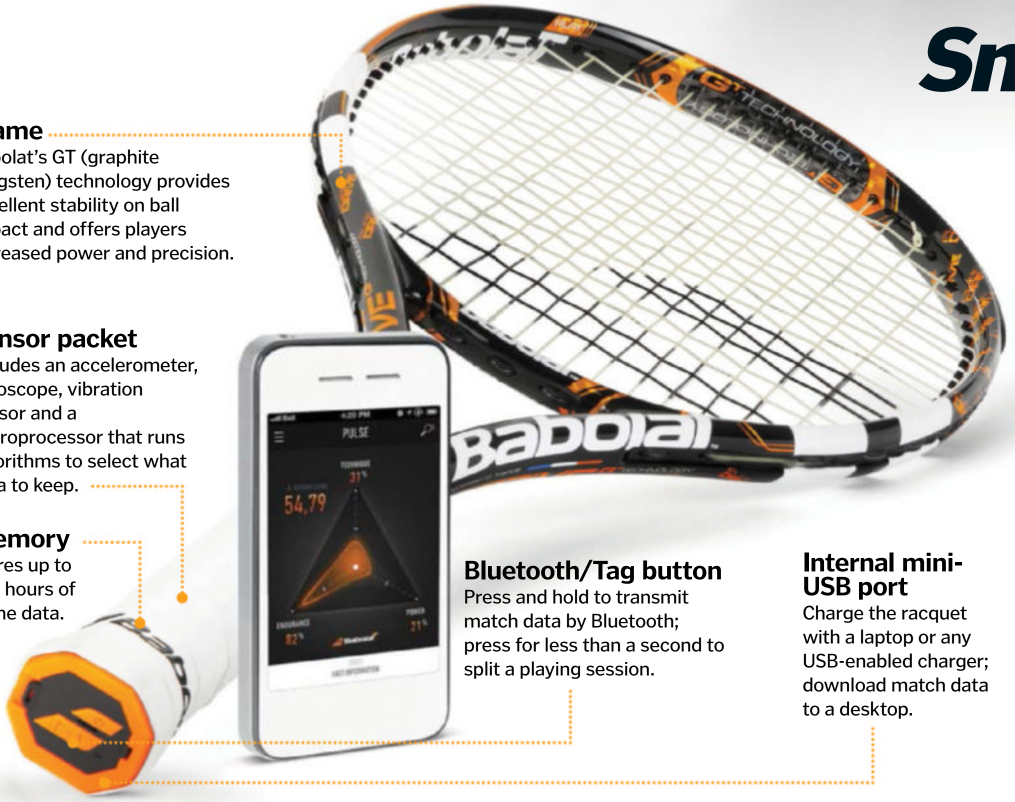
Power dock
A wireless induction cradle charges the ball cable-free; a full charge takes about an hour and is good for about 2,000 kicks.

Surface
Thermally bonded synthetic leather in a standard 32-panel, size-5 match-ball layout.

Smart racquet

Become a tennis ace with a racquet that records and rates your returns

If you're serious about your tennis session, you might want to check out the latest offering from the one of the sport's oldest manufacturers. The Babolat Play looks deceptively normal, but a bundle of sensors integrated into its handle tracks all aspects of your game including the number and type of strokes (forehand, backhand, overhead smash or serve); detail about these strokes (whether your forehand slices hit flat or with topspin); where the ball made contact with the string bed; rally duration; swing power and more. Transmitted via Bluetooth to an accompanying app, the data can be used for stroke refinement, post-match analysis or to compete with other aficionados.



Frame
Babolat's GT (graphite tungsten) technology provides excellent stability on ball impact and offers players increased power and precision.

Sensor packet
Includes an accelerometer, gyroscope, vibration sensor and a microprocessor that runs algorithms to select what data to keep.

Memory
Stores up to 150 hours of game data.

Bluetooth/Tag button
Press and hold to transmit match data by Bluetooth; press for less than a second to split a playing session.

Internal mini-USB port
Charge the racquet with a laptop or any USB-enabled charger; download match data to a desktop.

Fitness bands

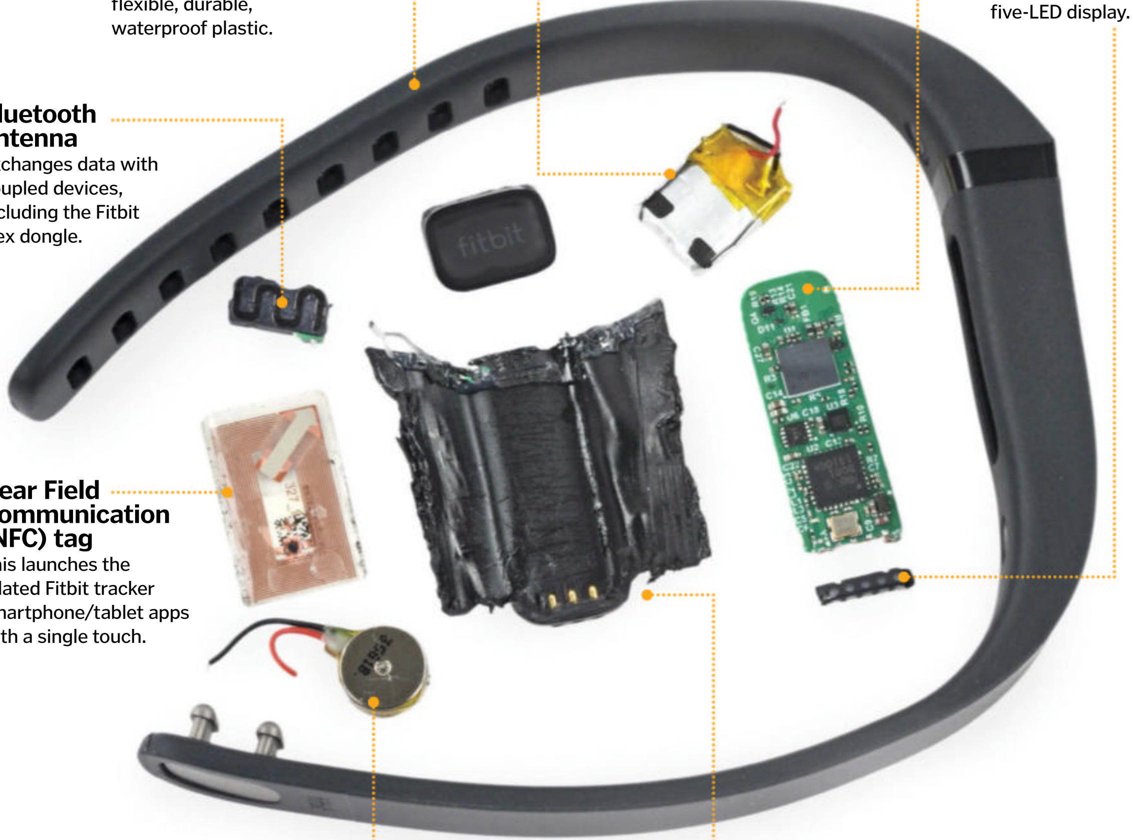
Leading you by the wrist toward good habits and health

Just a couple of years ago, fitness bands graced the wrists of only the techiest Silicon Valley types, but their mainstream acceptance has been swift, with tens of millions welcoming them as a chance to become more mindful about their daily choices. In fact, sales of fitness bands grew by over 500 per cent between 2013 and 2014.

Even the most basic models will count your steps, track your calorie consumption, and communicate this data to an accompanying smartphone app, most commonly via Bluetooth. More advanced versions record the distances you cover, the heights you scale, when you break a sweat, how hard your heart beats, and even how well you sleep. Some even offer helpful suggestions, like alerting you if you've spent too long in the Sun or providing encouragement to hit your goals.

Inside the Fitbit Flex

Getting to grips with this mysterious black band



Battery
Lithium-ion polymer battery charges in three hours and lasts up to five days.

Motherboard
Where the brains of the Flex live, including an accelerometer and microprocessor.

Light guides
These transmit light as part of the five-LED display.

Wrist strap
Made from lightweight, flexible, durable, waterproof plastic.

Bluetooth antenna
Exchanges data with coupled devices, including the Fitbit Flex dongle.

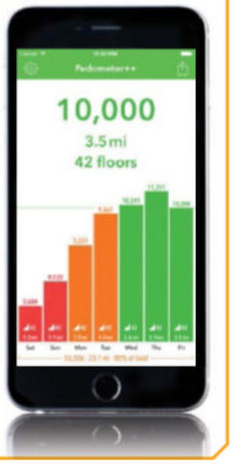
Near Field Communication (NFC) tag
This launches the related Fitbit tracker smartphone/tablet apps with a single touch.

Vibrator
Indicates when you turn different modes on and off or achieve a goal, and acts as a discreet wake up alarm.

Case
It has a rigid plastic skin, with built-in waterproof electrical contacts, to protect components.

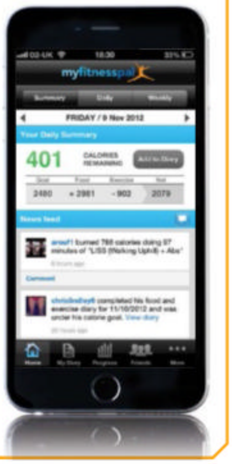
Activity

Apps use a variety of different sensors – either within your smartphone or dedicated wearables – to analyse your activity levels. Pedometers are usually based on accelerometer technology and determine the number of steps you take; GPS trackers log the distances you cover; and altimeters measure how much climbing you do – whether that's up the stairs in your home or up the North Face of Everest. Many wearable fitness trackers give extra insight into how hard you're working by recording your heart rate, and some even log your blood-oxygen level – a telltale indicator of respiratory health.



Nutrition

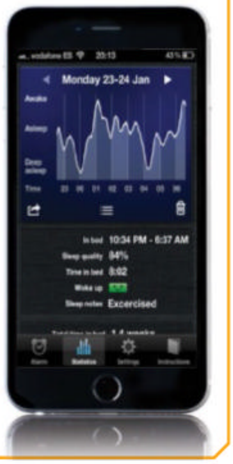
Unlike many health and fitness parameters, which can be tracked automatically by technology we carry or wear, nutrition tracking takes a bit of conscious input from you. Apps such as MyFitnessPal have huge built-in databases of foods. As you log what you eat, the apps break each item down into its nutritional components to give you a detailed picture of your daily diet. To make life a little easier still, some apps let you add dishes you regularly cook at home, others enable you to scan the barcodes of packaged foods, while some even include menus from popular restaurants.



Sleep

Sleep-analysis apps use data about your heart rate, breathing rate and how much you wriggle around, to calculate the hours of sleep you get and what proportion of it is light, deep or REM sleep – the kind where you dream.

During deep sleep, for example, your heart rate drops, your breathing slows and deepens, and your body is very still. Sleep data can be collected by various different wearable sensors or devices placed under or atop your mattress. Advanced systems also log ambient conditions such as temperature, light and noise levels to allow you to pinpoint possible sleep saboteurs.



Blood-pressure monitor

Keep an eye on your blood pressure and keep your doctor in the loop too!

Blood pressure is a hidden health indicator that has a big impact on your long-term physical condition. If you suffer from high blood pressure (hypertension), or are just keen to keep tabs on your metrics, an at-home monitor is a must. Withings' version comprises the standard self-inflating cuff that measures your systolic and diastolic pressures along with your heart rate. These are transmitted instantly via Bluetooth to a smartphone app that gives you feedback, history and the option to send readings along to your doctor.

Blood-pressure readings are automatically synced to your smartphone

Sleep tracker

Sleep – and wake – smarter by scrutinising your shut-eye

Quality rest is essential for us to feel and perform our best. The Withings Aura uses a 15-millimetre (0.6-inch)-thick Sleep Sensor pad, placed under your mattress, to monitor your sleep cycles by tracking your heart rate, breathing rate and body movements throughout the night. A companion bedside device emits soothing sounds and a reddish glow, which does not inhibit the production of melatonin – the hormone responsible for making us sleepy – in the brain. In the morning, it emits stimulating noises and invigorating blue light designed to gently bring you into your lightest sleep phase so that you awake feeling refreshed.

Aura gets your day off to the best start by gently easing you from your slumber

Smart scales

Get more out of your weekly weigh-in with scales that chart your fitness progress

The effects of positive lifestyle changes are more nuanced than simply your weight on the scale, but the Withings Smart Body Analyser paints a clearer picture of how your body is changing. It measures your weight; body composition – or lean mass versus fat; your standing heart rate; and the ambient air quality, which affects how restorative your sleep is. These metrics are transmitted to a smartphone app, where you can track your health goals, sync the data with other fitness apps and even tweet your achievements to the world!

Body fat is calculated by passing a tiny electrical current through the soles of the feet

World's first intelligent yoga mat

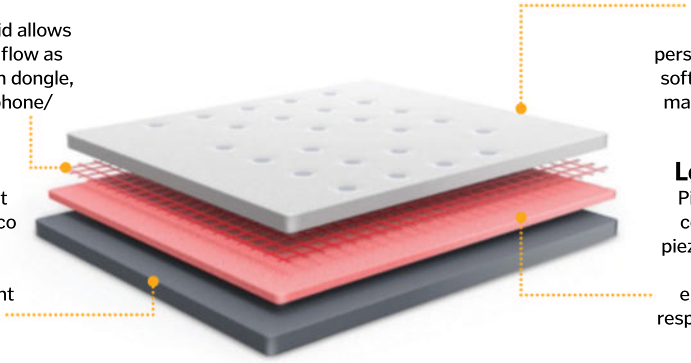
Forget communing with your inner self and get ready to commune with your yoga mat

SmartMat is a smart, responsive yoga mat that uses an inbuilt array of pressure sensors to study your balance and alignment. Used in conjunction with a smartphone or tablet app, it gives you real-time feedback – voice commands or silent visual tips for when you're in a class. It determines the 'perfect pose' by taking into account factors such as user height, weight, gender and age. This is all part of the calibration process, which includes lying down on the mat so it can determine your Ape Index (ratio and length of torso versus legs). It uses piezoelectric sensors within the mat to measure changes in pressure and forces by converting them to an electrical charge – known as the piezoelectric effect.

The SmartMat app offers guided workouts with constant feedback on form

Upper interior
Conductive fabric grid allows generated charge to flow as electricity to the tech dongle, which doubles as a phone/tablet stand.

Top surface
Wipe-clean, perspiration resistant, soft-textured surface made from a custom Eco PVC material.



Base layer
Durable, 100 per cent latex-free, flexible, Eco PVC made with SmartGrip Surface Technology to prevent slipping and sliding.

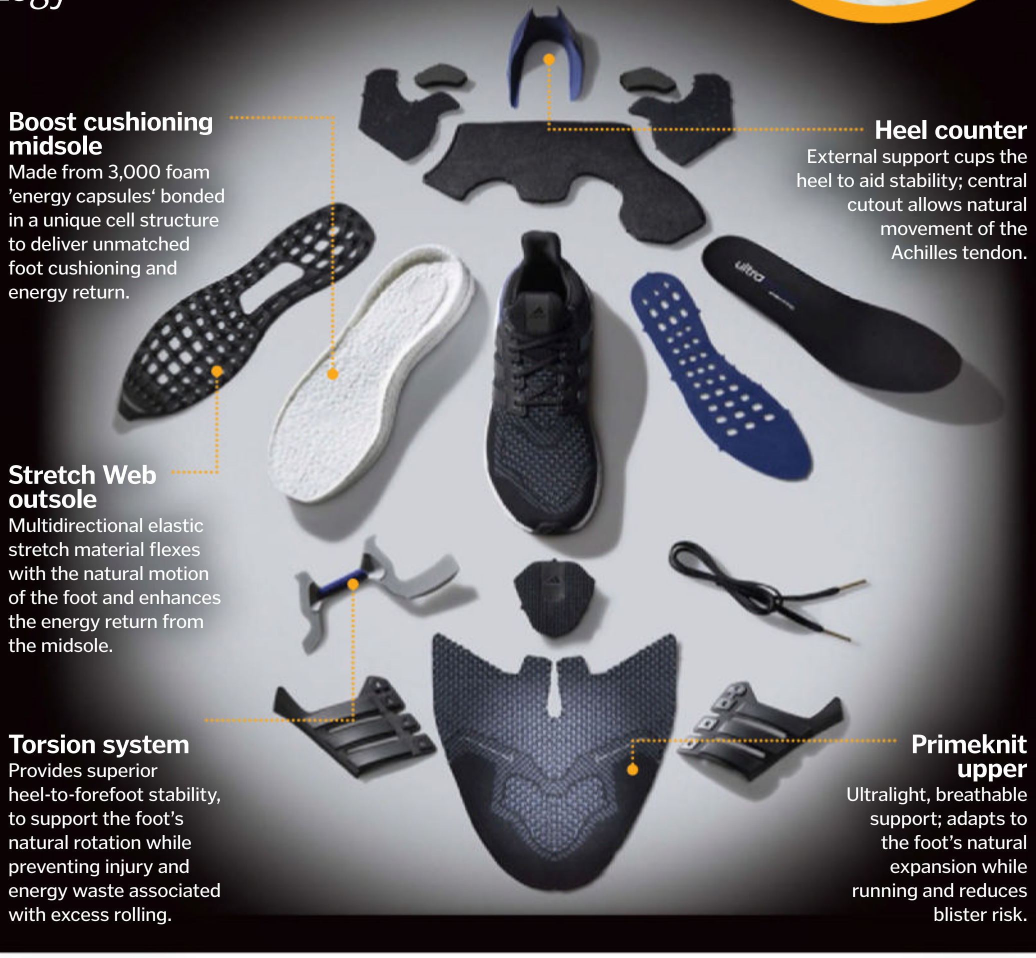
Lower interior
Piezoresistive layer comprising 21,000 piezoelectric sensors that generate electrical charge in response to pressure.

Revolutionary running shoes

Put your best foot forward with today's turbo-powered trainer technology

At the core of Adidas' Ultra Boost trainers are midsoles constructed from thermoplastic polyurethane (TPU) material. This is comprised of thousands and thousands of tiny beads, packed together to provide unrivalled springiness and temperature modulation. TPU is said to be more flexible than most air-cushioned trainers, which use ethylene vinyl acetate (EVA) – an elastic substance – and Adidas claim this advanced material offers 20 per cent more energy, boosting the performance of athletes. Another positive effect is that it provides cushioning that protects the joints, which is crucial for long distance runners.

The outsole – a stretchy elastic webbing – is designed to adapt and move with the foot, expanding over the duration of a punishing training session. It incorporates Adidas' Primeknit technology, where a single piece of yarn is knitted and attached to the sole of the shoe and then subsequently treated with water-resistant polymer. This differs from traditional boots that are stitched to laminate pieces. To top it all, these kicks can supposedly hold up to hundreds of kilometres of pavement pounding, and thus have a long, durable life. No excuses now.



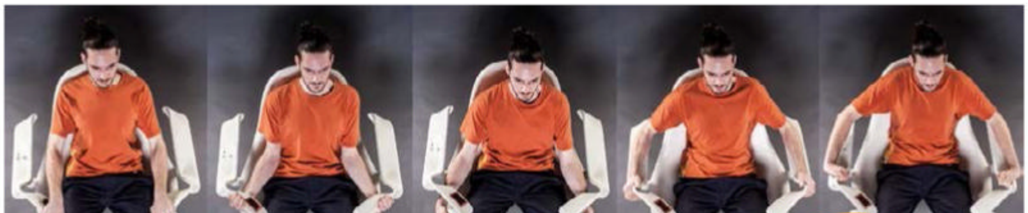
Boost cushioning midsole
Made from 3,000 foam 'energy capsules' bonded in a unique cell structure to deliver unmatched foot cushioning and energy return.

Heel counter
External support cups the heel to aid stability; central cutout allows natural movement of the Achilles tendon.

Stretch Web outsole
Multidirectional elastic stretch material flexes with the natural motion of the foot and enhances the energy return from the midsole.

Torsion system
Provides superior heel-to-forefoot stability, to support the foot's natural rotation while preventing injury and energy waste associated with excess rolling.

Primeknit upper
Ultralight, breathable support; adapts to the foot's natural expansion while running and reduces blister risk.



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264

Exercise while sitting down

Take a seat in your living room's secret gym

Even the most motivated health nut has days where they just can't drag themselves to the gym. To them, and to the couch potatoes of this world, the TAO Chair offers a laid-back alternative: a seated isometric resistance workout that targets the core, upper body and upper leg muscles.

The chair itself looks like something out of a design catalogue. Embedded in its folded ribbons of arms are sensors that monitor the force the sitter generates during grabs, pushes and pulls performed with their arms and legs. Calories burned show on an LCD display, while a companion app guides the workout.

DID YOU KNOW? *Three out of the top five race times in marathon history were run by athletes wearing the Adidas Boost shoe*

Fitness gaming

Engage your imagination and watch your workout fly by

Childhood and adult obesity levels have reached epidemic proportions in recent decades, with up to 37 per cent of 11 to 15-year-olds in the UK now classified as obese. A large portion of blame is attributed to the rise in sedentary lifestyles and the proliferation of videogames replacing outdoor play, but game-makers are fighting to turn the tables and make their products a force for good health.

Fitness gaming was arguably sparked by the worldwide craze for Japanese choreography arcade game *Dance Dance Revolution* back in 1998. Companies realised that "gameifying" exercise into physical challenges and group contests engaged that most irrepressible human attribute – the competitive streak – making workouts fun, exhilarating and, best of all, addictive.

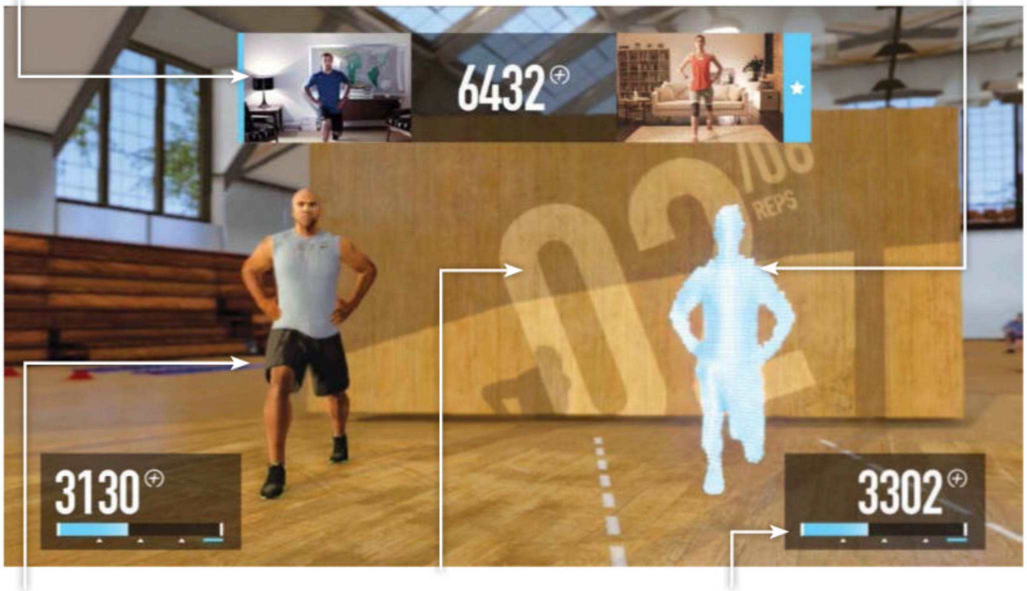
Users young and old can get a kick out of racing Mario in the 400-metre hurdles or stepping onto Centre Court to do battle with a global tennis star. These kinds of activities are facilitated by handheld controls and smart play surfaces, with built-in sensors to track players' movements. With this approach, working out becomes easier and more fun.

Nike+ Kinect Training

Let a virtual trainer put you through your paces and ignite your competitive streak

Partner workout
Connect remotely with friends to work out together and keep each other motivated.

Avatar
Your on-screen representation, extracted by the camera-based Kinect sensor system, lets you see how your movements compare to Coach.



Virtual trainer
Programmed by some of the world's best Nike coaches, it gives you detailed pointers and encouragement.

Counter
This displays info like how many seconds of a drill remain, or how many reps you've completed.

Nike Fuel score
Earn points for form, speed and endurance; compete against a partner or against your own personal best.

Magnetic dumbbells

Lifting and other weight training requires a lot of bulky equipment, which can be a problem for people who travel a lot, find it hard to get to a gym, or have limited space at home to store the equipment. But in the future help may be at hand in the form of a pair of smart bracelets that – literally – promise to take the weight out of weight lifting.

The O2 Magnetic Dumbbells, designed by students at Kookmin University in South Korea, are a pair of electromagnetic rings worn above and below the elbow. The rings can be set to attract or repel one another, and the electric power can be altered to control the strength of the magnetic force and provide degrees of push and pull resistance from three kilograms (6.6 pounds) right up to 24 kilograms (52.9 pounds), and can provide a challenging workout for almost every level of fitness.

Unlike traditional weights, these babies won't blow your baggage-allowance budget and they're small enough to carry anywhere with you, for whenever you get the urge to pump some electromagnet. These are not recommended if you have a pacemaker though.

1 in 10
AMERICAN ADULTS OWN SOME FORM OF FITNESS TRACKER

$50 BILLION
PROJECTED 2018 VALUE OF FITNESS WEARABLES INDUSTRY

54%
OF FITNESS TRACKER OWNERS ARE FEMALE

20 MILLION
FITNESS BANDS SOLD IN 2014

100,000+
HEALTH AND FITNESS TRACKING APPS IN THE APP STORE

14.1%
OF US CONSUMERS USE SMARTPHONE HEALTH APPS

$26 BILLION
PROJECTED 2017 VALUE OF GLOBAL HEALTH AND FITNESS APP MARKET

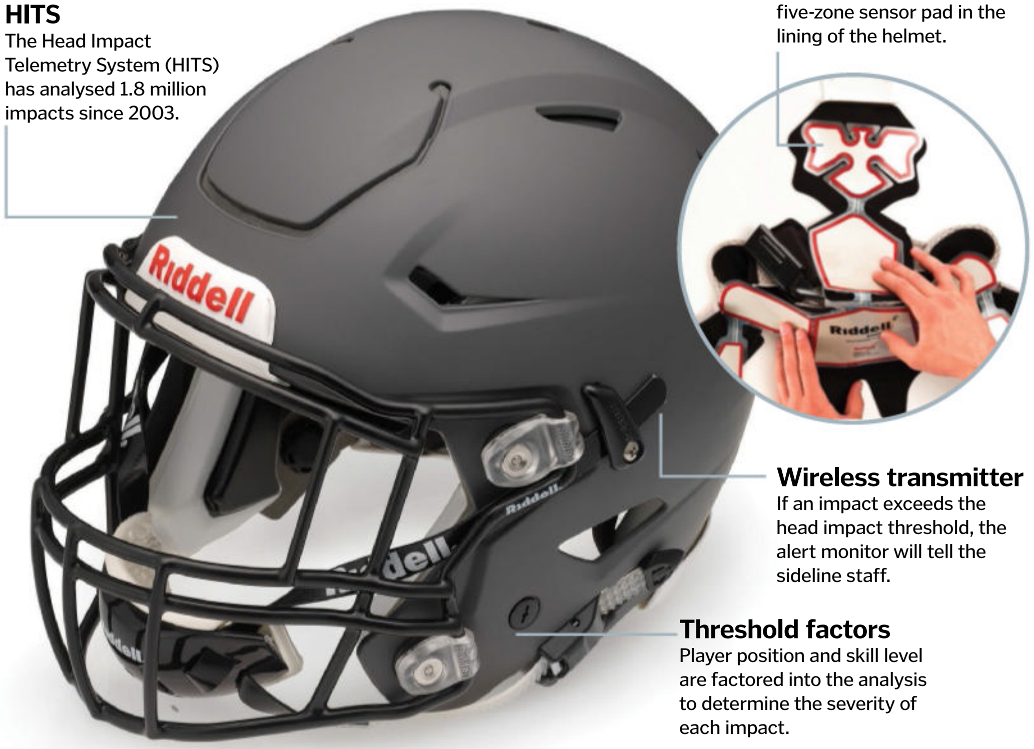
© Babolat; Adidas; Withings; SmartMat; Thinkstock/Ingram Publishing; iFixit

Smart football helmet

Learn how this tech monitors the head impacts of NFL players

According to the NFL's data, 692 concussions were diagnosed in players between 2012 and 2014. Further to this worrying statistic are the findings of 79 deceased NFL player autopsies; 96.2 per cent of the subjects had suffered from a degenerative brain disease called chronic traumatic encephalopathy (CTE). Players are bigger and faster than ever before, making the dangers of head trauma even more severe.

American sports equipment company Riddell has designed the InSite Impact Response System (IIRS) to help reduce the risk of this. The system is composed of the Player Unit, Alert Monitor and Player Management Software. The Player Unit lines the helmet, and features a five-zone sensor pad measuring impact severity. This reports when a player experiences a singular or set of impacts exceeding a specific danger threshold. It measures impact by assessing the effects of duration, location and the type of acceleration the head experiences, combining these readings for the most accurate assessment.



HITS
The Head Impact Telemetry System (HITS) has analysed 1.8 million impacts since 2003.

Sensor pad
The player unit features a five-zone sensor pad in the lining of the helmet.

Wireless transmitter
If an impact exceeds the head impact threshold, the alert monitor will tell the sideline staff.

Threshold factors
Player position and skill level are factored into the analysis to determine the severity of each impact.

How guitar amps work

Discover how they can convert the sound of strings into a thundering stadium anthem

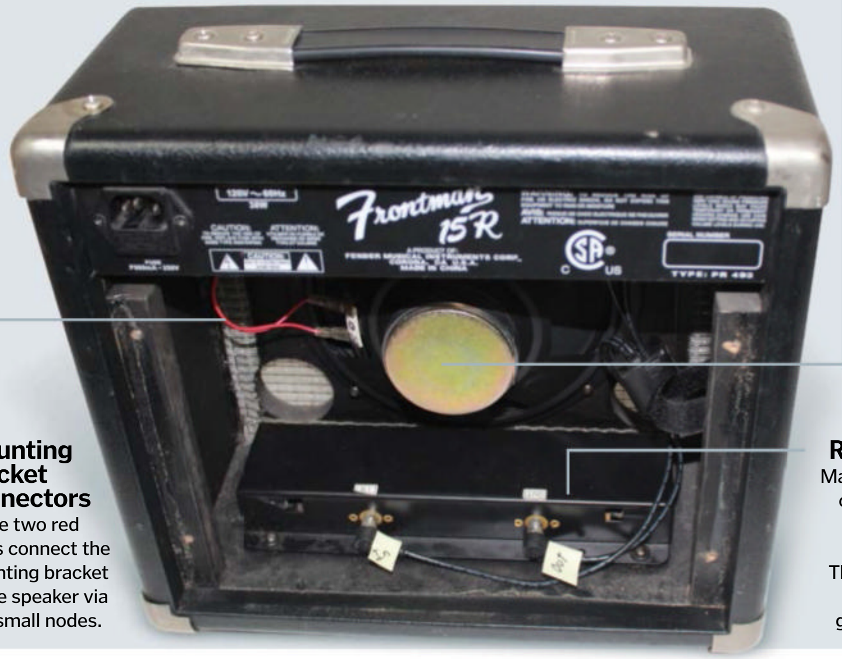
It is widely accepted that the introduction of the guitar amplifier changed music forever. Whether you're into Jimi Hendrix or Eric Clapton, it's hard to imagine either without their legendary riffs blasting out through amps.

A three-way process is used to amplify the strings' sound. The strings vibrate at a particular frequency; once plucked their signal passes through the guitar's pickups to the preamplifier. The preamplifier boosts the voltage of the signal generated by the guitar. The preamp also reduces the noise and interference within the guitar's sound, which could distort the resulting overall sound when amplified.

The power amp now amplifies the whole signal and sends it to the speaker, which emits the guitar's sound at an adjustable volume. Amps for both the electric and acoustic guitars as well as bass guitars are commonplace today, shaping the sound of all genres of modern music.

The 'combo' amplifier

Inside a combination guitar amp that contains both the amplifier and speaker



Speaker
This part of the amp produces the amplified sound. The wattage, and therefore power, can vary depending on preference.

Mounting bracket connectors
These two red wires connect the mounting bracket to the speaker via two small nodes.

Reverb box
Many amps now come with the reverberation effect built in. This imparts an echo on the guitar's sound.

© Riddell; ifixit

DID YOU KNOW? *To build the lagoon, over 25,000m³ (882,867ft³) of on-site material and 400 tons of recycled metal was reused*

The world's longest man-made waves

Deep in north Wales' Conwy Valley, a giant underwater snowplough is rolling out some serious swell

Surfer Miguel Pupo rides the man-made waves at a Wavegarden test facility in Spain

Wave hunters – rejoice! In an old aluminium quarry in north Wales, an inland surf facility is edging ever closer to completion and when it opens, surfers from across the globe can visit to ride the world's longest man-made waves.

Surf Snowdonia is a £12 million ($18.7 million) project built by surfers, for surfers. The engineers of Wavegarden are keen wave riders, and wanted to create something remarkable that can help existing surfers to train and budding wave riders to learn, without having to wait for unpredictable waves at the coast.

The technology that can create these waves looks a lot like a giant snowplough. It is pulled smoothly along underwater (with a protective covering to keep surfers safe) through the centre of the 300 metre (984 foot) long lagoon, pushing the water ahead of it into large, tubing waves that the designers claim are just like, if not better than, shredding the real thing. At their highest point the waves can reach two metres (6.6 feet) high and peel for 150 metres (492 feet), which is the equivalent of a 20-second ride for the surfer.

At a rate of one wave generated every minute, the waves that are created by the expertly engineered snowplough-like wave foil also interact with the contours on the bed of the lagoon. This provides different and predictable wave profiles at various points of the pool, meaning that there's a place at the lagoon for surfers of every age and ability.

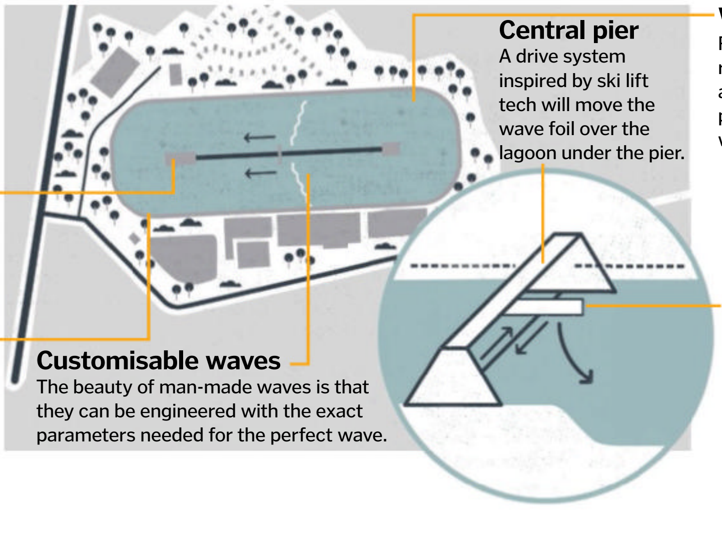
Wave machine vs ocean waves

Most ocean waves begin out at sea and are a product of the wind blowing over the water's surface. This causes friction and as the wind continues to blow, the wave builds and builds. A 'singular' wave extends vertically down the water column and so as it approaches the shore, the shallow water causes drag on the 'base' of the wave. This causes the wavelength to shorten, which forces the crest of the wave higher until it eventually spills over itself and breaks, like the waves we see crashing on the shore.

The difference between these waves and those at Wavegarden's Surf Snowdonia is that the man-made waves don't have the wind to whip them up, nor miles of ocean to grow in size and power. Instead, the wave foil smoothly 'shovels' the water in front of it, pushing it upward and ahead, mimicking the very last stages of a breaking ocean wave on the shore.

Totally tubular tech!

A tour of the artificial surfing lagoon that creates consistent and perfectly-formed waves



Computer tech
At each the end of central pier, towers house the computer-based technology that controls the wave foil.

Lagoon lining
The unique grid-like shore lining of the lagoon is designed to dissipate the energy created by the waves.

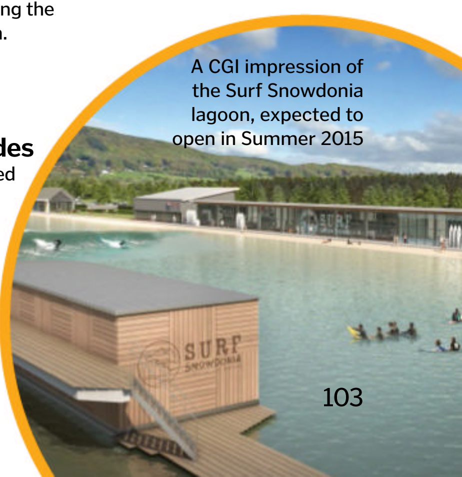
Customisable waves
The beauty of man-made waves is that they can be engineered with the exact parameters needed for the perfect wave.

Central pier
A drive system inspired by ski lift tech will move the wave foil over the lagoon under the pier.

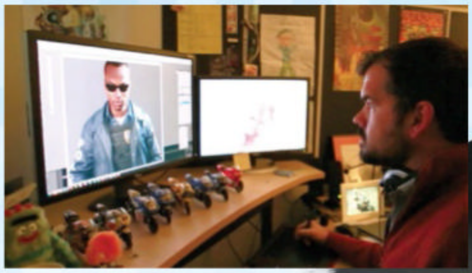
Water supply
Rainwater from mountain reservoirs will pass through a nearby hydroelectric plant before powering the waves in the lagoon.

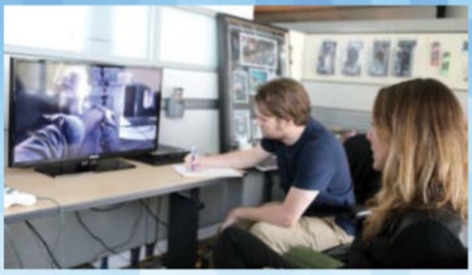
Surfers galore
Up to 52 surfers at a time will be able to ride the waves in the lagoon.

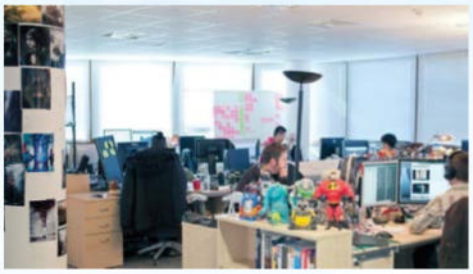
Reversible rides
The plough is pulled forward and back across the lagoon, so surfers are able to ride waves in both directions.


A CGI impression of the Surf Snowdonia lagoon, expected to open in Summer 2015

© Wavegarden







HOW VIDEOGAMES ARE MADE

Discover the incredible journey from concept to console

Playing a videogame is like entering a whole new world full of sights, sounds, artificial intelligence, simulated gravity and unique environments. The traditional videogames, such as *Mario* and *Space Invaders*, relied on consoles or arcade machines to work, but nowadays gaming is everywhere: on your phone, on your tablet, even in your TV.

It takes a variety of different skills on the journey between someone's first thought for a game and that same idea appearing in your hands. Some development studios employ hundreds of people, while other games are made with teams of only ten or less. It's not just a matter of knowing about the programming languages videogames are constructed with, development teams also have to learn about 3D modelling or pixel art to make the product look like a game, and they have to master audio design and sound-mapping to make the product sound like a game too.

The first thing a studio needs when making a new game is a plan that includes a plot, a cast of core characters and some sort of interactive action. These three elements are typically mapped out and combined during the 'pre-production' period – storyboards, concept art and vertical slices (a finished portion of a game) are designed here. These early tests are compiled into a game design document – a visual guide that details everything; from how menus work and character backstories, to how far a character can jump and level design.

Once a game design document has been created, the more technical side of development begins. This is a more interactive step in the game-making process, where programmers and coders will decide upon the engine they'll be using to build the game, and start to create playable situations where the team can test certain 'states' of their build. Big-budget games require a huge selection of programming tasks to be undertaken at this stage, including the simulation of in-game physics, the scripting of the AI and the generation of menu elements (or the user interface).

Programming is typically undertaken in the game's codebase – think of it as a library of information the game can constantly pull material from. A codebase is a script unique to each game, and isn't dissimilar from a huge computer summoning documents from files stored on its drive. If a game knows it needs to show three enemies and an explosive barrel on screen, the codebase will be organised so the game's script can easily and quickly find those assets and load them.

DID YOU KNOW? *Super Mario Bros* was drawn out on graph paper before being 'written' into the game's coding language

BRINGING THE GAME TO LIFE

Without the skills of the programming team, you wouldn't be able to get past a game's title screen

Physics programmer

Everything you touch in a game has a real-world weight, resistance and shape to it. It's down to the physics programmer to make sure that all in-game 'gravity' works as it needs to, so that it's not too heavy or too light.

AI programmer

Enemies in games would be boring if they always acted the same way. So it's the AI programmer's job to create scripts that inform how they react once they spot you, as well as where to patrol and how often they need rest.

Audio engineer

Just because the audio team has made the sounds for the game, that doesn't mean they'll trigger when they need to. The audio engineer maps out the sounds to places in the world, including voice acting and even music.

Input programmer

Are you playing on an iPad or a PlayStation, and with touch controls or a joypad? The input programmer determines this and ensures all player commands are 'listened to' by the game.

Level designer

Every obstacle, every enemy and every wall to climb over, has been intentionally thought about to challenge the player and make them learn more about the game's mechanics. That's the level designer's job.

Systems designer

A game like *Pokémon* works by running a highly advanced set of algebraic formulas off against each other. It's the systems designer that ensures the maths behind these formulae is perfect and bug-free.

Network programmer

If a game has any online functions or can be played in multiplayer mode, a network programmer needs to oversee production on how your game will communicate with other players' games, and how the code will cope with 32 players at once.

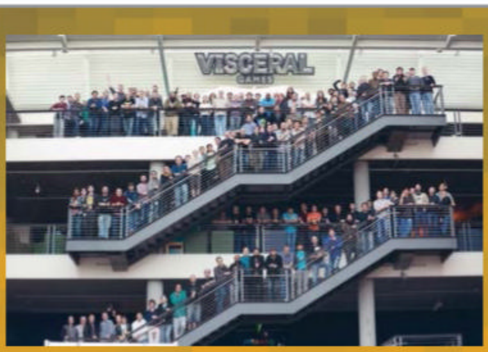
Narrative designer

The narrative designer works with the writer to make sure still open-ended games still make sense when played 'out of order'. Most games have over 30,000 lines of dialogue these days, so this role is a mixture of word and maths-based programming.

Most modern titles run on game engines which can interpret and 'translate' script. Amazingly, many of these are available for free to anyone interested in learning how to use them. These engines – Unreal, Unity, CryEngine, UbiArt – can simulate physics, graphics and sound at the press of a button, meaning developers and programmers can test out their codes much faster with an engine than without one. Studios may have specific roles for people that know how to use an engine, or a programmer might be able to perform both tasks on the same project.

By now, the main game 'mechanics' will be in place. Think of these in terms of gameplay – Mario's jump, *Sonic the Hedgehog*'s spin-dash, *MineCraft*'s building; these are all classed as mechanics. It's at this point that the graphics team steps in. If the studio has decided their character will be a human (or even just humanoid), a motion capture (or MoCap) team can begin work on recording and implementing real-world movements by mapping them onto an in-game character. If the characters are monsters, dragons or something else entirely, the animators and 3D artists will get to work on putting these together. There are many different programs capable of creating 3D art, so it's important to ensure the 3D engine will 'speak' to the game engine – a game wouldn't work if none of the characters' costumes loaded onto their bodies; you'd just see the 3D skeleton of a stickman walking around! Lastly, a sound design team must ensure all the sound-effects – from gunshots to bridges creaking – are in place. This can be done by recreating them within the game's engine, or recording them and applying them to the in-game world.

There can be hundreds of people working in any one game studio, but that doesn't mean smaller groups of people can't design their own game. It's possible for a single person to release a game on their own too, if they can learn the very specific skills required to produce an interactive story! Over the next few pages, you'll learn exactly how a game goes from a concept to your console.



The 250-strong team at EA studio Visceral Games are responsible for the likes of *Battlefield: Hardline* and the *Dead Space* franchise

THE TEAM BEHIND A VIDEOGAME

Designer

A designer can be seen as the studio 'head', like a film director. It'll be their vision and their ideas that the game is based on.

Programmer

The person responsible for making sure the game does what you tell it to do, the programmer writes scripts for in-game 'mechanics'.

Artist

All the original visuals stem from the artists; they will provide the concept sketches, landscapes, character clothing and details.

3D artist

The member of the team responsible for re-creating the artist's work in 3D; producing textures, working on weapons and armour and even making terrain.

Animator

The animator will make the 3D artist's characters come to life, either through manually creating scripts that make figures move, or by applying motion capture data.

Producer

A jack-of-all-trades that makes sure the development deadlines are on track. They also acquire funding or other necessary assets for the development studio.

Writer

The author of the game. Writer's jobs can vary from providing a key narrative arc for the game to giving in-game characters scripts or backstories.

Audio programmer

Creating the sound is usually undertaken by a team of recorders and foley artists (who reproduce everyday sound effects).

Game Tester

Referred to as 'bug hunters', the quality and assurance team find parts of the game that don't work properly and log them for programmers to fix.

© Thinkstock

Game production milestones

A development studio must complete many 'milestones' in order to get their game into your hands

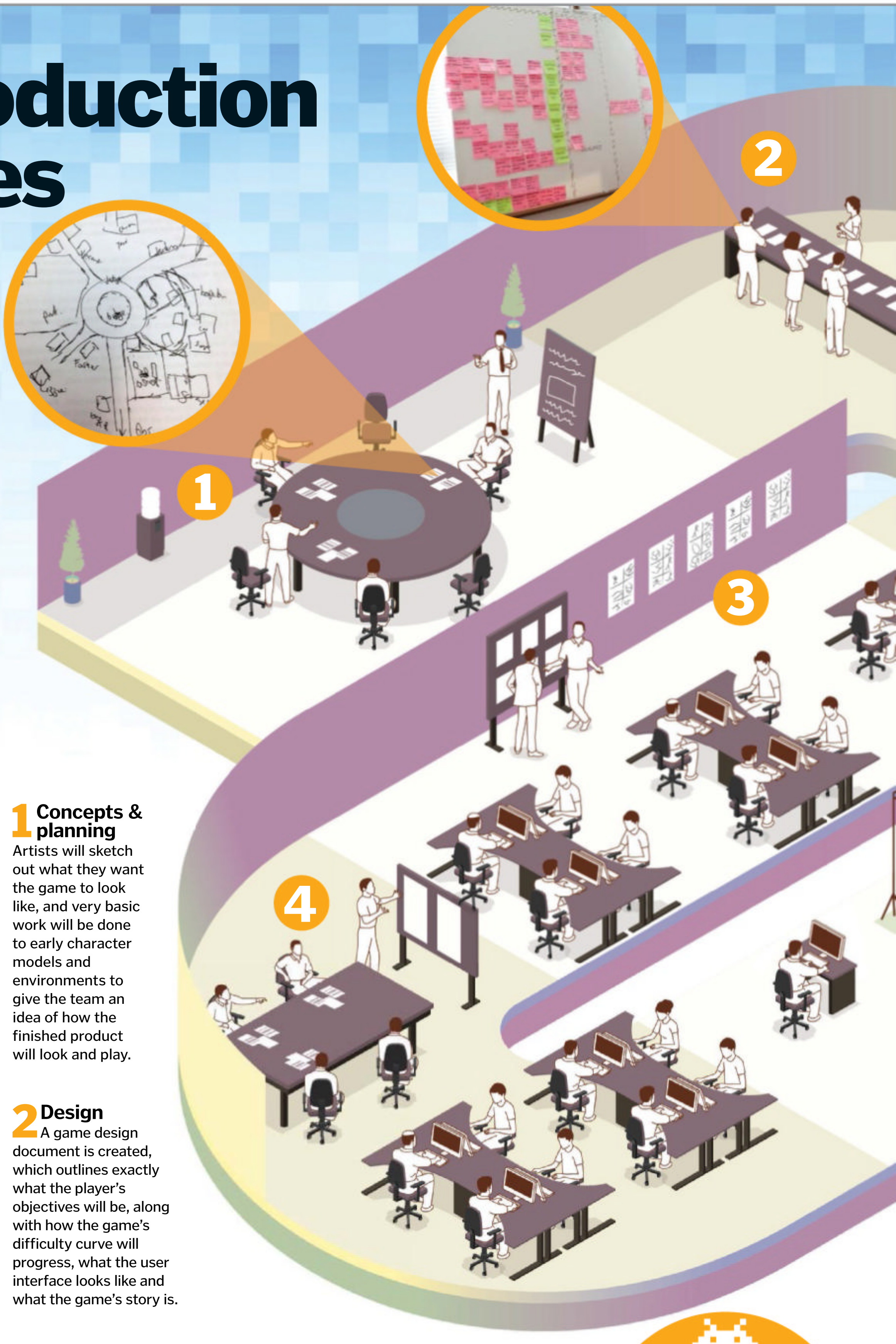
Videogame development is hard to track; after all, there are so many different parts of the game that are being worked on simultaneously, that it's difficult to measure how close to completion a game actually is. As such, development studios use 'milestones' to gauge their progress and mark major achievements in their projects. There is no industry standard when it comes to milestones, but a typical game – which takes roughly two years to make – would follow a pattern similar to this.

The first playable: The first playable state is exactly what it sounds like – the very first draft of a game that contains gameplay and assets representative of the final product. This build will be very closely based on what's outlined in the game design document, and is typically ready 12 to 18 months before a game's release.

Alpha: The alpha stage of development is when all of the key gameplay elements have been implemented. Ideally, a game in alpha should be 'feature complete', which means the product contains all the ideas and controls that will be used in the final build. The codebase should be roughly 80 per cent complete at this point, and programmers will focus on finishing this before adding extra content or features.

Beta: A game in its beta phase is practically complete. The design team has signed off the product as 'code freeze', a term implying that no more code may be added to the game, and only bugs or glitches may be addressed. A beta build will contain near-complete graphics and might only lack some precise details, such as the way some in-game items behave with the environment, for example.

Going gold: Once a game 'goes gold', it's officially out of the studio's hands. The final build of the game is signed off and sent to be printed onto Blu-ray discs, cartridges or computer chips (for arcades), and a digital copy is sent to publishers who'll host the title on their online stores once release day hits.



1 Concepts & planning

Artists will sketch out what they want the game to look like, and very basic work will be done to early character models and environments to give the team an idea of how the finished product will look and play.

2 Design

A game design document is created, which outlines exactly what the player's objectives will be, along with how the game's difficulty curve will progress, what the user interface looks like and what the game's story is.

3 Engines & coding

An engine is chosen for the game and this will determine the software tools the programmers will work with as production continues. All the interactive elements of the game – from controller input to character movement and more – are designed and implemented here. Programming languages like C++, Python or BASIC are used to fine-tune details that the engine can't manage.

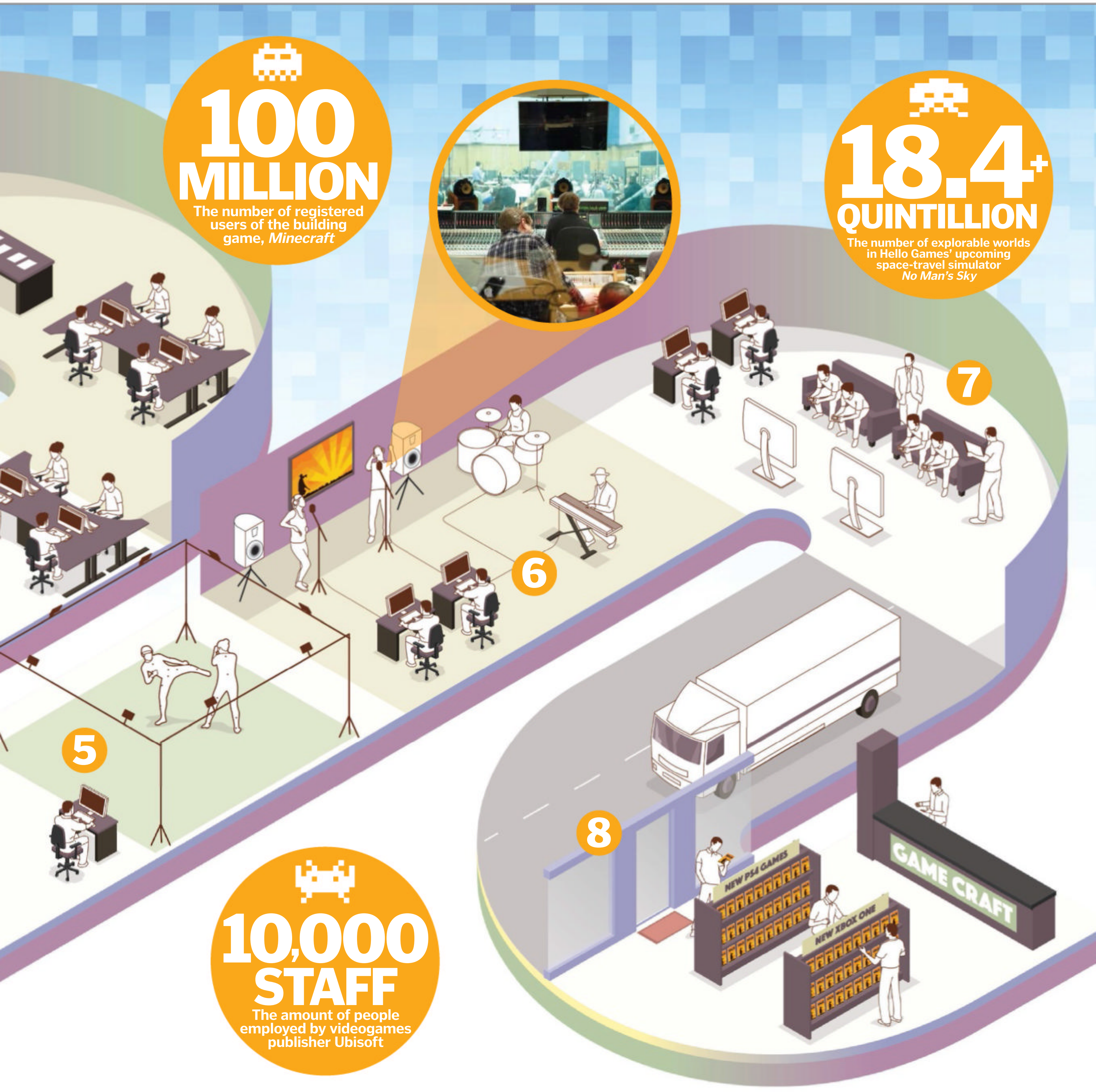
4 Character creation

In-engine tools and separate 3D art software are used to build characters from the ground up. Each individual part of the character is worked on first – the body, the hair, the face, the clothes – until eventually every bit of the model is put together. New software is in development all the time, allowing for more lifelike creations. For example, TressFX is a system built specifically to render realistic hair.

$265 MILLION

The amount of budget it took to make *Grand Theft Auto V*

DID YOU KNOW? Nintendo, publisher of the *Mario* and *Pokémon* games, actually began life as a playing cards company in 1889!



100 MILLION
The number of registered users of the building game, *Minecraft*

18.4+ QUINTILLION
The number of explorable worlds in Hello Games' upcoming space-travel simulator *No Man's Sky*

10,000 STAFF
The amount of people employed by videogames publisher Ubisoft

5 Motion capture

Once the character models are in place, actors resembling their physical shape are hired and kitted out in special suits that read their movements in a 3D grid. The actors perform actions – drawing a sword, rolling forward, dodging and so on – and all the data is extrapolated from the 3D grid and translated into in-engine sequences that programmers can apply to certain inputs or commands.

6 Sound design & scoring

A composer will receive an early (alpha) build of the game and play through it to get a feel for the atmosphere and tone, before creating a soundtrack based on this. Music design now tends to be dynamic, meaning composers must create their tracks so they can seamlessly transition, depending on where the player is moving or what actions they are performing. Sound effects are recorded by foley artists – who recreate various noises in a studio – and implemented here, too.

7 Debug & testing

Once all the characters, music, mechanics and graphics are in place, the game is released into its 'beta' phase. Here, teams of people systematically play through the game and log and errors or glitches in the code. These logs are compiled into reports and delivered to the core development studio at regular intervals, where the programmers dig into their old code to find, fix or replace bad lines of code that are causing the crashes or errors.

8 Pre-release

The game goes 'gold' (ready to be printed to disc) and a final build is packaged together and sent to manufacturers. Alternatively, the package is sent to a publisher (like Microsoft, Sony or Steam) and is hosted on that company's own digital storefront.

Illustration by Acute Graphics

Creating realistic characters

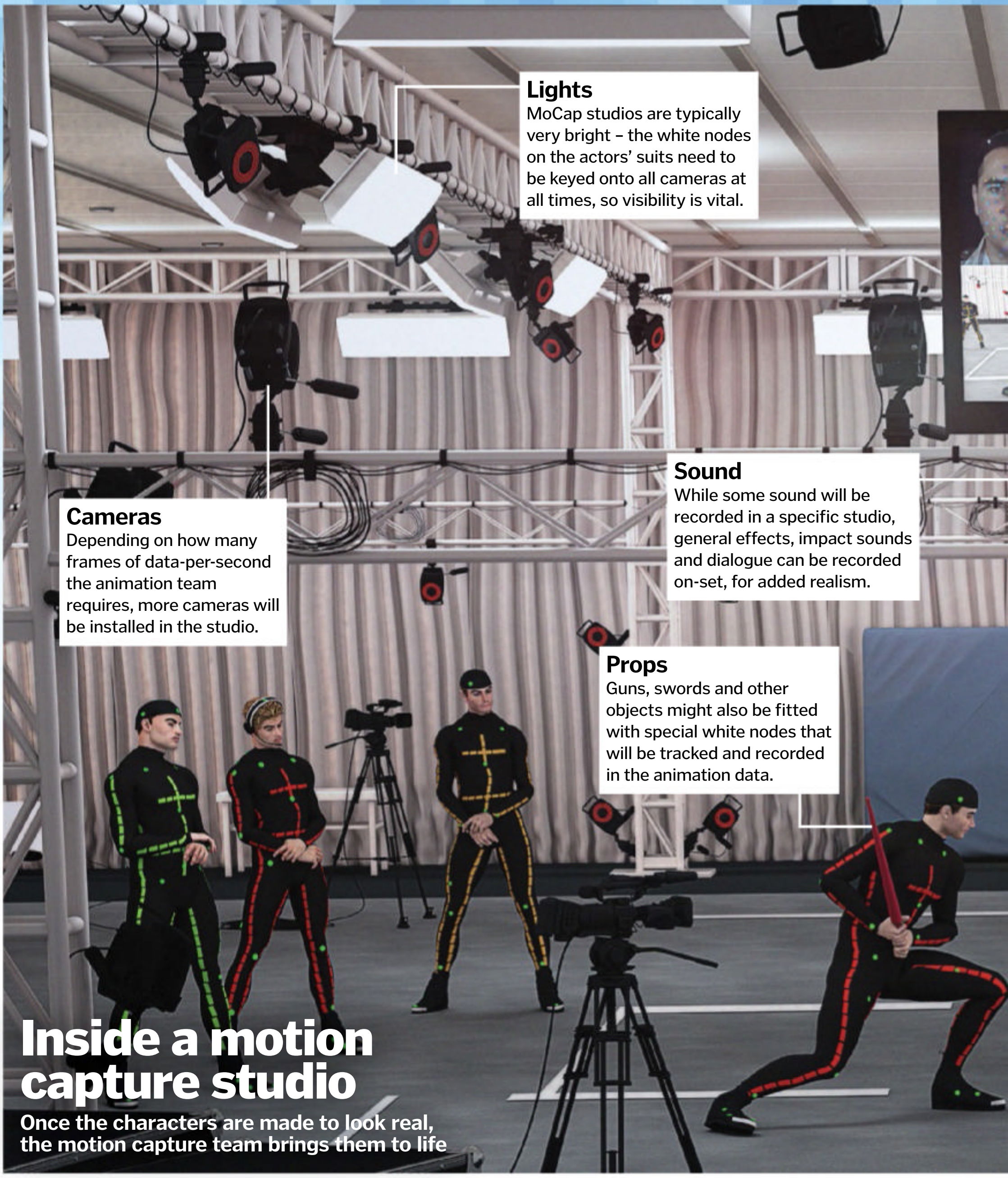
Having a lifelike cast of characters helps gamers believe in a fictional world

Videogame characters are reaching new heights of realism, to the point where it's normal to see pores in skin, minor cuts and bruises, and even flakes of snow settle on a costume. In the case of Lara Croft – in Crystal Dynamics' reboot of the *Tomb Raider* series – the team scanned an actress who shared the same proportions. Laser fields mapped out her body shape, and recorded every detail on her skin.

This data was then translated into 3D rendering software, where programmers could single out certain planes of the model and label them for quick access later. For example, a graphics programmer could select particular areas of the model, label it as 'skin', and apply a realistic texture to that selection to lay the foundation of the character model. The process was repeated for every major part of the body before programmers moved onto the face. If the character being created is fantastical, however, programmers take reference scans of something similar and use that as a base. For example, a team in Germany – YAGER Development – were the first in the world to have motion-captured a cat!

3D faces used to be designed with 'bones' – reference points that could be manipulated to give the impression of facial expressions. A standard facial model ten years ago might have had 30 bones (the more bones, the smoother the animation). Nowadays, models are made with over 500 of these poseable points, which enable developers to animate faces to a more exaggerated (and readable) degree than what motion capture would pick up.

The final step is finding a voice actor for the role of the character. "I think that 99 per cent of a successful performance is in the casting and bringing people together," explains Troy Baker, the award-winning voice actor who has played many popular characters, including Joel in *The Last Of Us*. "We're starting to see an importance and a necessity in videogame storytelling for actors' performances to be of a high calibre." Voice actors can be recorded separately in studios, but this can lead to awkward dubbing where the tone of voice is disconnected with the character's actions on screen. Many studios now choose to have voice actors also providing the motion capture for their characters, so both the vocal and visual data can be recorded at the same time for a more realistic performance.



Lights
MoCap studios are typically very bright – the white nodes on the actors' suits need to be keyed onto all cameras at all times, so visibility is vital.

Cameras
Depending on how many frames of data-per-second the animation team requires, more cameras will be installed in the studio.

Sound
While some sound will be recorded in a specific studio, general effects, impact sounds and dialogue can be recorded on-set, for added realism.

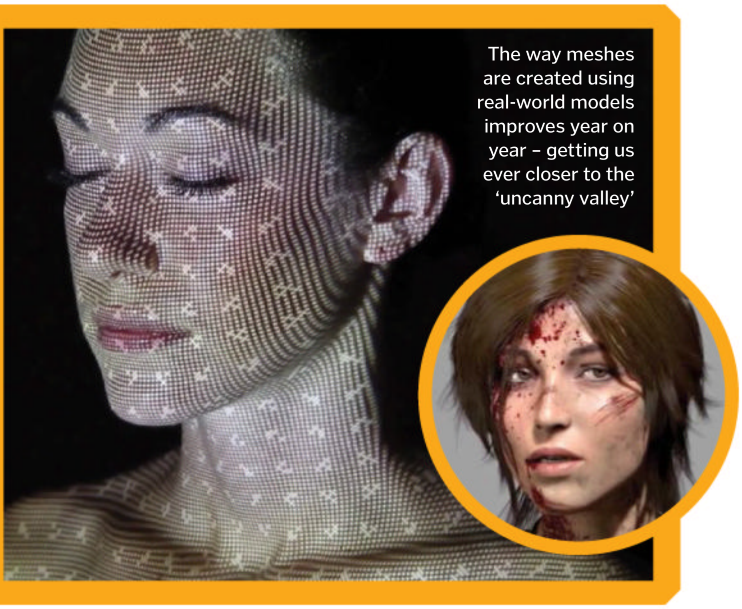
Props
Guns, swords and other objects might also be fitted with special white nodes that will be tracked and recorded in the animation data.

Inside a motion capture studio

Once the characters are made to look real, the motion capture team brings them to life

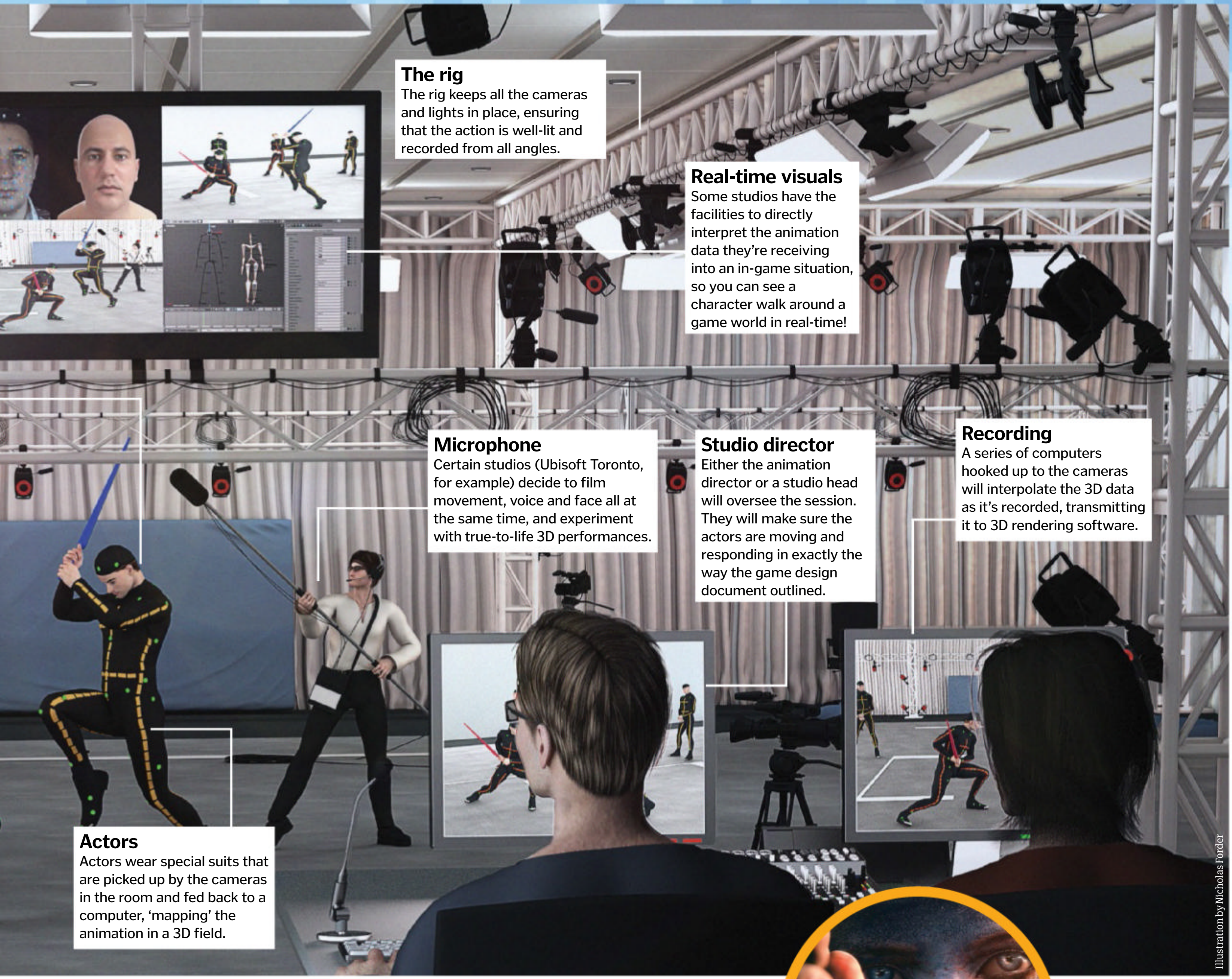
Realistic faces

The 'bones' traditionally used in facial animation are slowly being overtaken by new technology. In *Rise Of The Tomb Raider*, for example, a new tool called MOVA is being used. MOVA is applied as a 'spraypaint' to the face, and provides around 7,000 points of reference. Cameras are then moved extremely close to an actor's face to pick up thousands and thousands of data frames per second. Think of it as green-screen that can be painted on, making it easier for cameras to pick up key reference points so the nuances of facial expressions can be mapped to the character.



The way meshes are created using real-world models improves year on year – getting us ever closer to the 'uncanny valley'

DID YOU KNOW? *The development of Call of Duty: Black Ops II required the team to take motion capture data for a horse*



The rig
The rig keeps all the cameras and lights in place, ensuring that the action is well-lit and recorded from all angles.

Real-time visuals
Some studios have the facilities to directly interpret the animation data they're receiving into an in-game situation, so you can see a character walk around a game world in real-time!

Microphone
Certain studios (Ubisoft Toronto, for example) decide to film movement, voice and face all at the same time, and experiment with true-to-life 3D performances.

Studio director
Either the animation director or a studio head will oversee the session. They will make sure the actors are moving and responding in exactly the way the game design document outlined.

Recording
A series of computers hooked up to the cameras will interpolate the 3D data as it's recorded, transmitting it to 3D rendering software.

Actors
Actors wear special suits that are picked up by the cameras in the room and fed back to a computer, 'mapping' the animation in a 3D field.

Illustration by Nicholas Forder

Studio to screen

100 years ago, animators at Disney used live-action footage to 'trace' animations and then project them. That's fairly similar to how optical 3D motion capture works. Those white balls you see on MoCap suits are interpreted by software (like Autodesk's MotionBuilder) that project how the actor in the suit moves onto a skeleton character, which programmers can study in real-time. If the performance has unexpected results – which can happen due to the unpredictable nature of motion capture – a director will offer feedback to the actor that will directly affect the way data is produced on screen. This is a fairly modern practice, and is only a viable method of animating due to how quickly and efficiently modern computers can run.

Ninja Theory's *Hellblade* features the character Senua, whose MoCap was all achieved in a rig built by the developers themselves

Starting the engines

A game's engine is a software framework that interprets the code that videogames are made in, but there are many of them available for use.

Unreal
Unreal is a free-to-use engine that's been the most popular choice for developers in the last few years. It can deliver photorealistic graphics and lifelike lighting effects with minimal effort.

Unity
Modern independent developers have been using Unity due to its easily accessible interface and unique asset bank that enables you to use parts of games that other developers have made (if you pay for it!).

CryEngine
The most popular engine used to create photorealistic games; the CryEngine's drawback is that developers have to pay to use the engine. It's worth it when you see the final results, though!

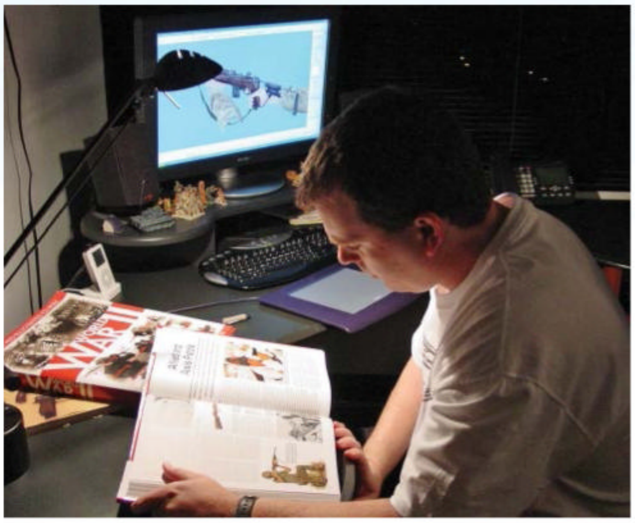
Starling FrameWork
The *Angry Birds* mobile game was made in this engine, which is based on the standard internet browser platform, Flash. The engine specialises in fast-paced 2D games.

SDKs are hard to come by but are vital when testing out new games

Tools of the trade

Having a computer that's quick and powerful enough to run a game-making engine is one thing, but having a place to fully test an early build of your game is another important requirement. These test units are called SDKs (software development kits) and are usually given to studios via the console manufacturers (Microsoft, Sony, Nintendo). Having a kit in the studio means programmers can 'debug' their games in real-time – most test modes of games have a special button that lets developers break through the graphics and interface, and interact directly with the code that's running the game.

These kits used to be incredibly hard to get hold of – they basically let you 'look inside' a console's code and alter your game's cyber DNA to suit it – but nowadays they're becoming more and more common. In fact, Microsoft shipped out over 1,000 of these SDKs to independent publishers in the last two years alone!



Q&A with an audio designer

Lionhead Studios' Steve Brown explains what's involved in creating sound for videogames

What is the most difficult part of your job when implementing new sounds into videogames?
Game audio needs to be strict – just because you've got 300 megabytes of memory to play around with, you still need to maintain good file management. You're easily going to accumulate 100,000 WAV files, so without a filing structure and proper editing, the right sounds will never trigger on the right animations, and it's a nightmare. It results in a product that never syncs up.

Has the way game audio works changed a lot since you began working in the industry?
In terms of audio production, big budget games get to spend a lot of money on foley, but you can get so wrapped up in it. You've always got to question: 'Does this sound give key gameplay feedback to the player?' If the answer's no, you scrap it.

That's actually how we work in feature films, too – even if we've got the budget to put every single sound that could possibly be there in the film, we realise that isn't what we want to do. It can end up detracting from the things we actually want the audience to listen to.

What is the most important thing that you've learned from being hands-on in your job?
The biggest thing I've learnt from film and foley is the confidence to just try things out. As an audio designer, I can sit there with a library of pre-recorded stuff or a commercially available library, and I can sit for hours just trying to edit out tiny little elements: cloth movement, for example. You could try and cut that, but a single run could take hours.

How do you go about recording sound effects for things like magic or fantasy-based things in games?
[One of our games, *Fable Legends*] has an ice character called Winter. For her, we had to get the sound of cracking ice, but that's really quiet! I'd stand on top of some glass, with a mic pressed against it, and we just had to make it break. We then put salt and tiles underneath the glass, too, so when you stand on it, you get this frozen ice-lake kind-of sound without actually having to freeze a thing.

We used a similar technique when working on [*Harry Potter and the Deathly Hallows*] when Harry meets a Patronus, but we adapted it for *Fable*.

Do games make you smarter?

Games often get blamed for making people unimaginative or lazy, but studies show the opposite!

Spatial intelligence

Neuroscientist Daphne Bavelier discovered that people who play games are more likely to notice small details, and can maintain their attention over a wider field of view.

Eyesight

People that play first-person shooting games tend to have better vision than those that don't, a University of Rochester study revealed. The games help boost your 'contrast sensitivity', meaning players can perceive finer differences between light and dark.

Social skills

A research review in the journal *American Psychologist* found that multiplayer games like *World of Warcraft* become virtual social communities that encourage cooperation, which can help the players develop social skills.

Problem solving

The *American Psychologist* also review found that games develop critical thinking skills by encouraging players to come up with creative solutions to problems, such as solving puzzles.

Logical intelligence

Bavelier's study also concludes that gamers are able to display more rapid decision-making abilities than non-players, and can solve problems quicker and easier using abstract thinking.

Sharpening skills

Games are used in training military personnel and game-like simulations aid practicing surgeons. This is because 'practice makes perfect' and the more times people perform a task, virtual or not, the better they become.

Brain 'age'

Believe it or not, playing a brain-teasing game for as little as two hours a week might prevent natural cognitive decline, according to a study carried out at the University of Iowa.

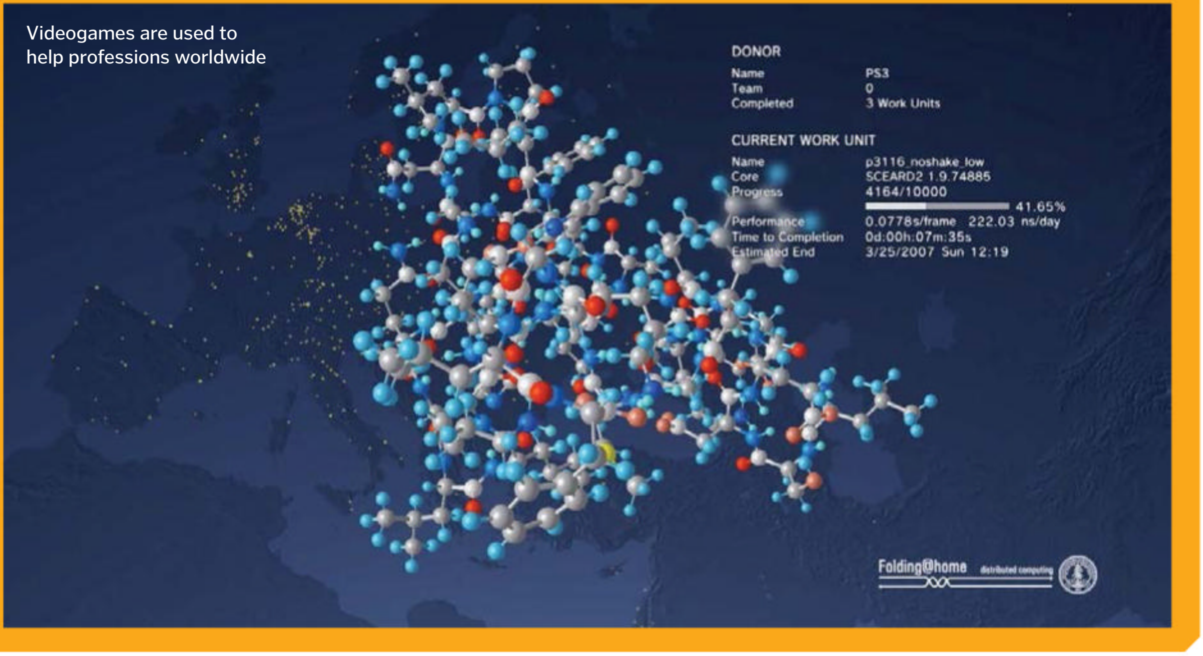
Motor skills

Researchers from Deakin University in Australia discovered that children between three and six years old, who played physically interactive games, showed more control over their limbs and improved motor skills compared to children that didn't.

Beyond games

Videogames and their tech aren't just used for entertainment; gaming interfaces are used to aid other professions in their roles. For example, an Xbox 360 game pad is used by the American military to control the High Energy Laser Mobile Demonstrator system, and the controllers that are used to pilot unmanned aerial drones are also modelled on game pads.

A project called 'Folding@home' used the processing power of your PS3 to help solve massive computational puzzles when the machine was not in use. *Minecraft* has been used by Britain's mapping agency, Ordnance Survey, to create a digital map of Great Britain using real-world geographical data.



Videogames are used to help professions worldwide

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DONOR
Name                  PS3
Team                  0
Completed             3 Work Units

CURRENT WORK UNIT
Name                  p3116_noshake_low
Core                  SCEARD2 1.9.74885
Progress              4164/10000
                                          41.65%
Performance           0.0778s/frame  222.03 ns/day
Time to Completion    0d:00h:07m:35s
Estimated End         3/25/2007  Sun  12:19
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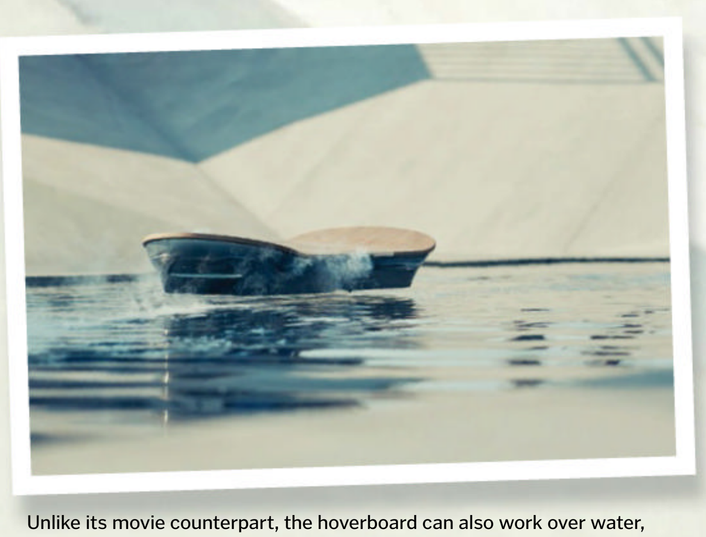
The hoverboard is here!

Lexus unveils a frictionless board from the future

We may not have flying cars and self-lacing shoes just yet, but another of *Back To The Future II*'s predictions for 2015 is finally coming true. Car manufacturer Lexus has created a working hoverboard that uses electromagnetism to enable it to levitate 2.5 to five centimetres (one to two inches) above the ground. However, before you get excited about being able to hover your way to work or school, there is a catch. The board will only work over special magnetic tracks and can be used for just 20 minutes at a time. At the moment it is just a prototype and won't be going on sale any time soon, but now Lexus has proved it can be done, who knows what the future might hold. ✱



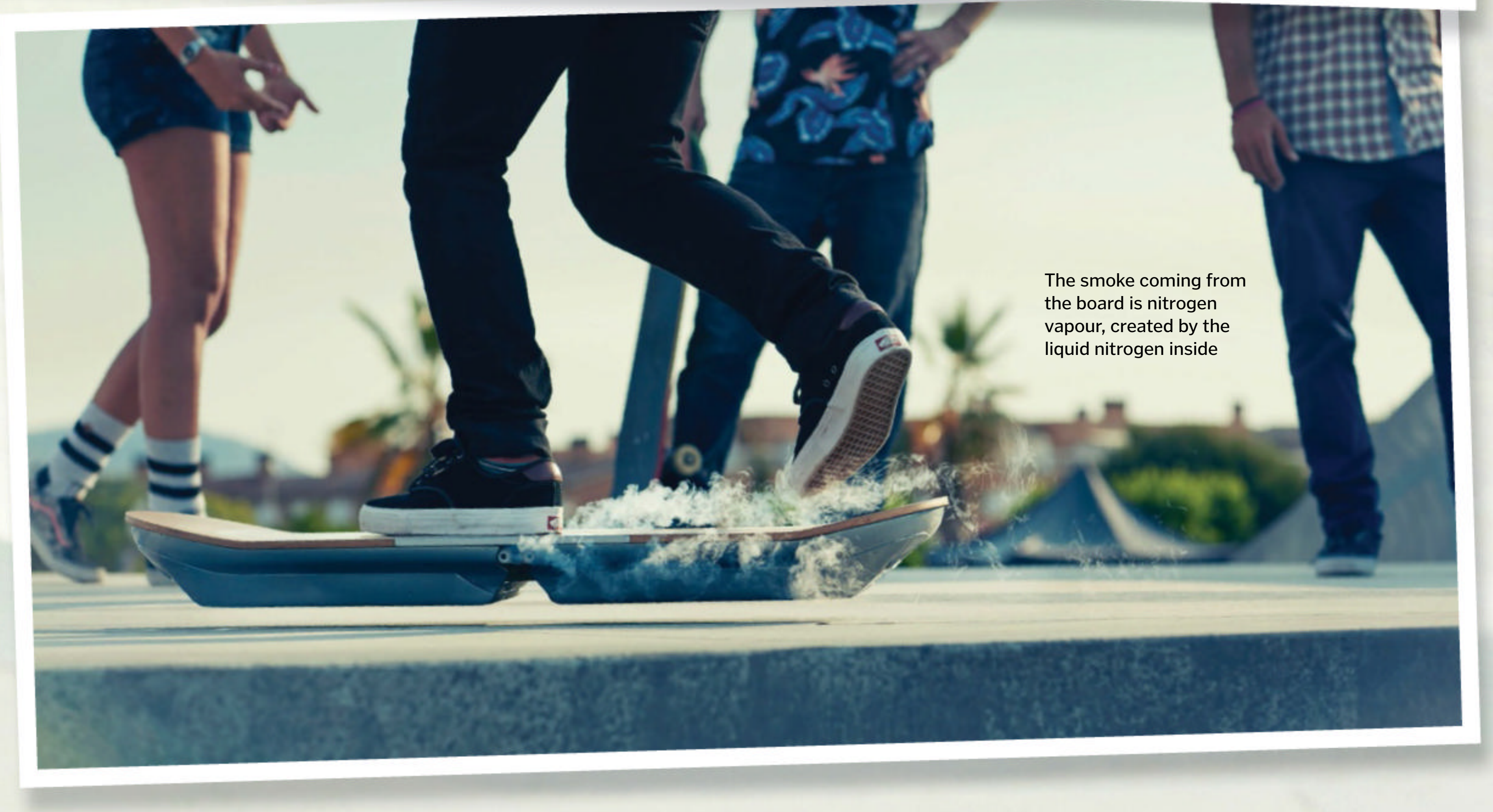
Unlike its movie counterpart, the hoverboard can also work over water, provided that there is a magnetic track underneath

DID YOU KNOW? *According to Back to the Future, hoverboards exist on the 21st of October, 2015. And they were right!*

How it hovers

The Lexus Hoverboard uses magnetic levitation technology, working in a similar way to the Shanghai Maglev Train in China. Inside the board is an insulated core containing high temperature superconducting blocks (HTSLs). These are housed inside cryostats – reservoirs of liquid nitrogen that cool the superconductors to their optimum operating temperature of -196 degrees Celsius (-321 degrees Fahrenheit). Acting as electromagnets, the superconductors create a magnetic field that repels the permanent magnets in the track below, enabling the board to levitate at a consistent height and support up to 200 kilograms (440 pounds). After about 20 minutes, the liquid nitrogen evaporates and the superconductors warm up, causing the board to fall back to Earth. To test it out, Lexus built a special 'hoverpark' in Barcelona, Spain, with magnetic tracks hidden beneath it, and got pro skateboarder Ross McGouran to have a go.

The hoverboard is about the size of a large skateboard and weighs about 11.5kg (25lb)

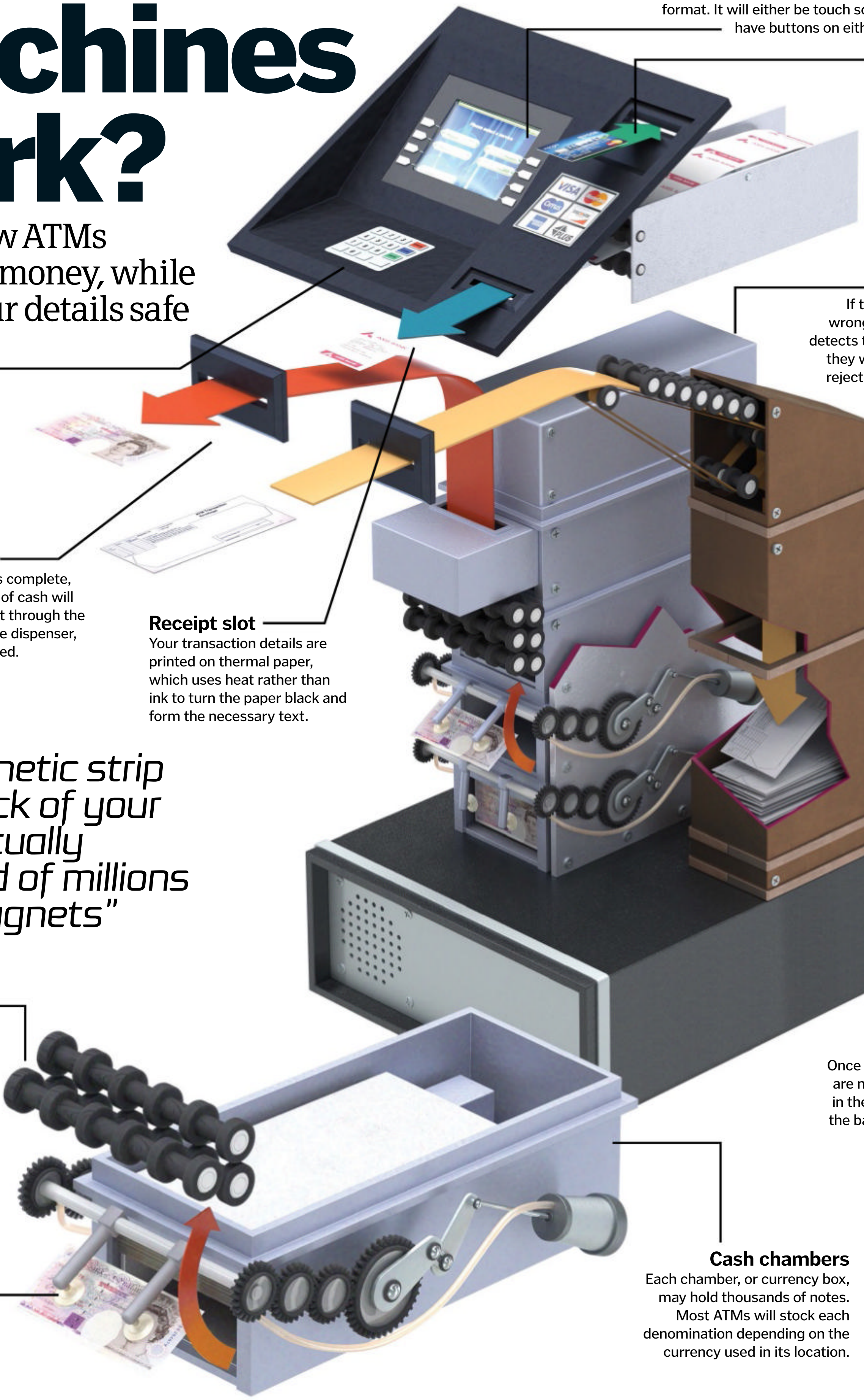


The smoke coming from the board is nitrogen vapour, created by the liquid nitrogen inside

© Lexus

How do cash machines work?

Find out how ATMs access your money, while keeping your details safe



Screen
The screen, commonly an LCD on modern machines, will prompt the cardholder through the transaction in a step-by-step format. It will either be touch screen or have buttons on either side.

Card slot
Once a card has been entered, its black magnetic stripe is read to authenticate the card and its owner.

Keypad
The keypad is where users enter their four-digit PIN. This is then sent to the cardholder's bank in an encrypted form in case someone intercepts it.

Reject box
If the machine pulls the wrong number of notes or detects that one is damaged, they will be dropped into a reject box and the process will be repeated.

Cash dispenser
Once the transaction is complete, the requested amount of cash will travel up from the vault through the roller mechanism to the dispenser, where it can be collected.

Receipt slot
Your transaction details are printed on thermal paper, which uses heat rather than ink to turn the paper black and form the necessary text.

> *"The magnetic strip on the back of your card is actually composed of millions of tiny magnets"*

Rollers
The rollers check the thickness of each note to make sure that two notes aren't stuck together, so the cardholder receives the correct amount of money.

Deposit box
Once cheques or deposits are made they are stored in the deposit box, where the bank will collect them at a later stage.

Cash chambers
Each chamber, or currency box, may hold thousands of notes. Most ATMs will stock each denomination depending on the currency used in its location.

Suction cups
The suction cups pick up notes individually, before the rollers process them.

Illustration by Nicholas Forder

DID YOU KNOW? *Gold to Go ATMs dispense gold bars and customisable gold coins instead of cash*

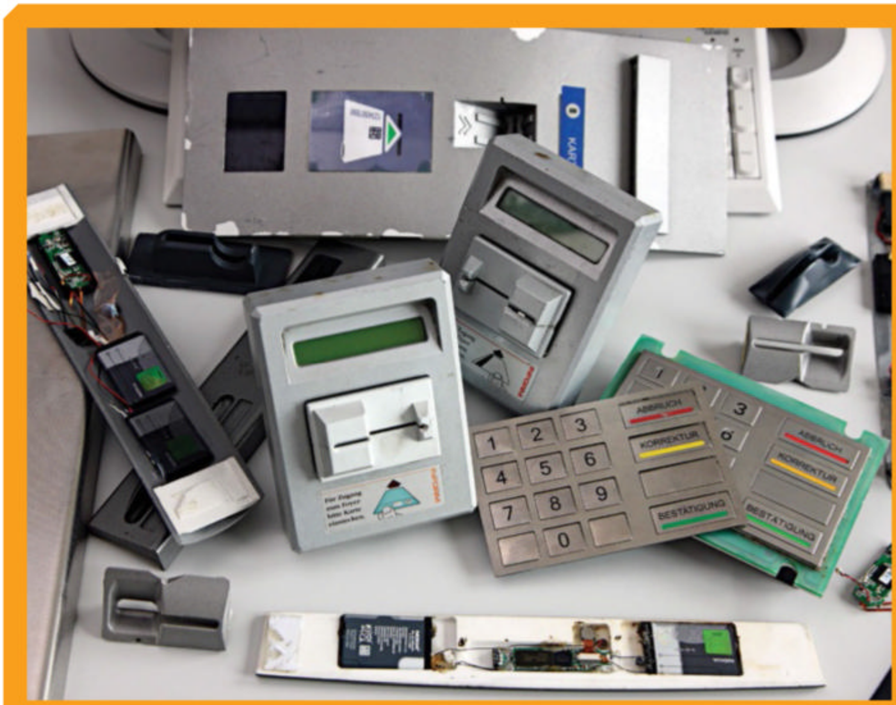
It's somewhat hard to imagine our modern world without cash machines, yet they only became the norm during the 1970s. The first machine that dispensed cash was invented by John Shepperd-Barron and was installed outside a branch of Barclays Bank in Enfield, Greater London.

Today, they work to give us access to our money 24 hours a day in a multitude of locations, and are far more convenient than queuing in a bank. However, there are many challenges for them to overcome in order to provide the required level of service. They have to check that you and your card are legitimate, find your account information and carry out the transaction required, all while protecting the thousands of pounds stored inside its vault.

The magnetic strip on the back of your card may look like a solid black line, but it's actually composed of millions of tiny magnets, each one magnetised either north or south, which two magnetic readers understand like a binary code. The first reader confirms the card is real, while the second reads your account number and PIN, checking this against the code that you entered on the keypad.

Once your PIN is confirmed, the machine automatically connects to your bank's network which relays a signal back to the built-in vault, giving it a specific set of instructions. The ATM will then complete the transaction that has been requested. If you forget to take your cash for whatever reason, modern cash machines will swallow the money after a short period of time so you won't be out of pocket.

PIN code shields similar to the one pictured are one way of reducing fraud



There are numerous ways that cash machines can be tampered with, from hidden cameras to card traps, so it is best to take precautions

The rise of ATM fraudsters

Today our cash machines are constantly under threat from organised crime, with a number of techniques available to criminals that can quickly and cheaply access your card details. The skimmer attachment is one of the most commonly used scams, and involves a small device being fitted to the cash machine which will then read and record your card details. Coupled with this is often a hidden camera, cleverly concealed in panels above the machine or somewhere nearby to find out what your PIN code is. Card traps are also becoming increasingly popular – they work by trapping your card in the machine for the fraudster to collect at a later date. To combat these problems, the police recommend that you always remain vigilant when using a cash machine. By checking for anything unusual or out of the ordinary, you can spot most attempts to rip you off, especially if you use the cash point in question frequently. Make sure you cover your PIN at all times and be wary of any suspicious bystanders hanging around the ATM.

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How YouTube works

The incredible technology behind the world's most popular video sharing site

You Tube
MacBook Air
HERO4

DID YOU KNOW? *The young stars of the 'Charlie Bit Me' viral video have made over £300,000 [$460,000] from the clip*

Since it first launched in 2005, YouTube has quickly become the number one destination for video content online, attracting over one billion regular users. The Google-owned site gained popularity by enabling people to share their videos with others all over the world, whether it's an amusing clip of their pet,or footage of them dancing in their living room.

It's not all about cute cat videos and funny home movies though, as YouTube has also helped people launch careers. For example, pop star Justin Bieber was first discovered when a talent scout saw videos of him singing on the site, and Zoe Sugg, aka Zoella, has got her own book deal and range of beauty products as a result of her popular video blog, or 'vlog'. You can even earn money directly from YouTube too, as the site shares some of the revenue it makes from companies who pay to run adverts before or over your video.

The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded as YouTube converts it into its Adobe Flash video format, with the file extension .FLV, for you. This enables the video to be played using YouTube's Flash player, which can be installed on your computer or smart device for free.

Another benefit of YouTube is the ability to embed videos on other websites. By simply copying and pasting a bit of HTML code, you can enable people to watch a video on your own website using the YouTube player. This saves you having to host the video on your site which requires a lot of bandwidth. Bandwidth is the range of signal frequencies needed to transmit data over the internet and you have to pay for ▶

> *"The popularity of YouTube is mainly down to how easy the website is to use. Videos in a range of file formats can be uploaded"*

The most watched YouTube video ever is currently Gangnam Style by Psy, with over **2.3 billion** views and counting

YouTube sensation Zoe Sugg, aka Zoella, films her beauty videos in her bedroom

Going viral

How to become a YouTube celebrity

1 Find your niche
Choose a topic or theme for your YouTube channel that's interesting and or entertaining, and hasn't been done before. For example, YouTube celebrity Zoella gives fashion and beauty tips and reviews her favourite products.

2 Create a studio
You could film your video using your smartphone, but for a more professional look, set up a camera on a tripod. Either make use of the natural light by shooting outdoors or in a well-lit room, or you can set up your own lighting.

3 Upload your video
Finish off your video using editing software, cutting out unnecessary footage and making sure the audio can be heard. Now create a YouTube account and upload your video. The site will automatically convert it into the correct Adobe Flash video format for you.

4 Give it a title
When naming your video, make sure you include any keywords relating to the topic featured and think about what sort of terms people might search for to find it. Also give it an appropriate thumbnail image and a comprehensive description.

the amount you use. YouTube streams vast amounts of data each day, carrying the bandwidth burden for other sites that want to display video.

Although embedding is great for spreading your videos further across the internet, most people will actually find them simply by searching. To help connect users to the videos they are looking for, YouTube uses a complex algorithm made up of over one million lines of code. When you search for a video, the algorithm decides which search results it will show you and in what order. One of the main factors used to rank the results is video metadata. This is the title, description, thumbnail and tags that you give your video when you upload it, so you should make sure they are relevant to the content of the video and what people might search for to find it. However, the other ranking methods YouTube uses are out of your control. The site used to rank its videos by how many times they had been viewed, but this presented a few problems. It often meant that new videos were pushed to the bottom of the list as their view counts had not yet had a chance to grow, and it also enabled people to manipulate their ranking by clicking on their video repeatedly, as clicking the play icon counts as a view. To combat these problems, YouTube has switched to a new system of measuring a video's quality by the length of time it has been watched for. If several users have stopped watching after a few seconds, this suggests that the video had a misleading title or thumbnail and didn't give viewers what they were looking for, whereas if they stayed to watch until the end it was most likely appropriate for the search terms used and therefore worthy of a high ranking. The rest of YouTube's ranking tricks are a mystery though, as the company is very secretive about its algorithm and changes it all the time to stop people manipulating it. What we do know, however, is that YouTube does take some steps to ensure a video's view count indicates it's quality and this is highlighted by the mysterious number 301. You may have noticed, that as a video's view count climbs, it quite often pauses at this number for a few hours or even days. This is because when a video reaches just over 300 views, a team of YouTube employees has to verify that the number accurately represents the popularity of the video. They do this by analysing the viewing statistics to make sure people are watching the video all the way through and not just clicking play to raise the count. While they do this, the view count is frozen at 301 until it has been confirmed as genuine.

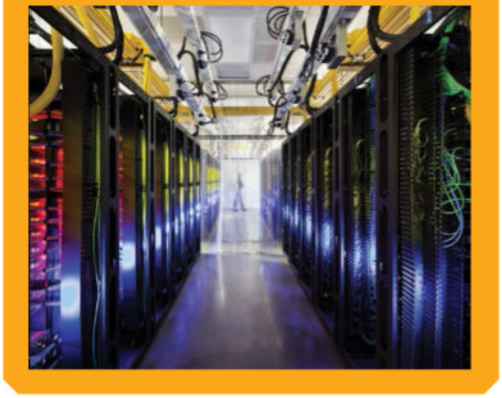
Over 500 years of YouTube videos are watched on Facebook every day

> "The site used to rank its videos by how many times they had been viewed, but this presented a few problems"

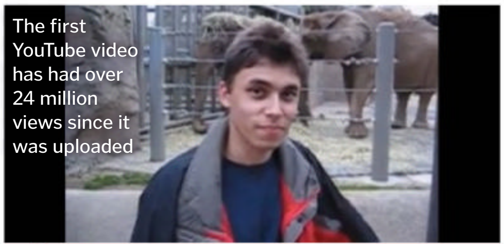
Video storage

Every video uploaded to YouTube is stored in at least one of Google's 14 data centres spread across the world. These enormous buildings contain thousands of servers – the powerful computers that handle the billions of Google searches made every day and also store your videos. Giant cooling towers keep the temperature inside at a steady 27 degrees Celsius (80 degrees Fahrenheit) to ensure the equipment runs smoothly, and each piece of data is stored on at least two servers for extra security. The data centres can also communicate with each other to send information between them. When you upload your video it will be stored at the data centre nearest you, but when someone wants to play it, the video will be sent to their nearest data centre for quick access. This also means that in the event of a fire or other disaster, the data is sent to another data centre so that it's always accessible.

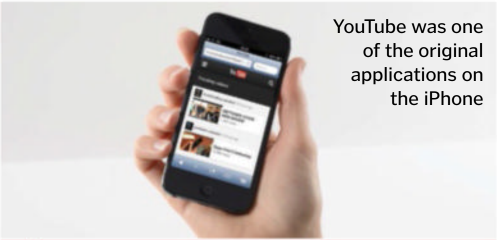
Google data centres can be found in Europe, Asia and North and South America



A brief history of YouTube



The first YouTube video has had over 24 million views since it was uploaded



YouTube was one of the original applications on the iPhone

2005
The first YouTube video was uploaded by the site's co-founder Jawed Karim. It's an 18 second clip of him at the zoo.

2006
Google buys YouTube for £883 million ($1.65 billion) in shares. The site now has around 72 million visitors each month.

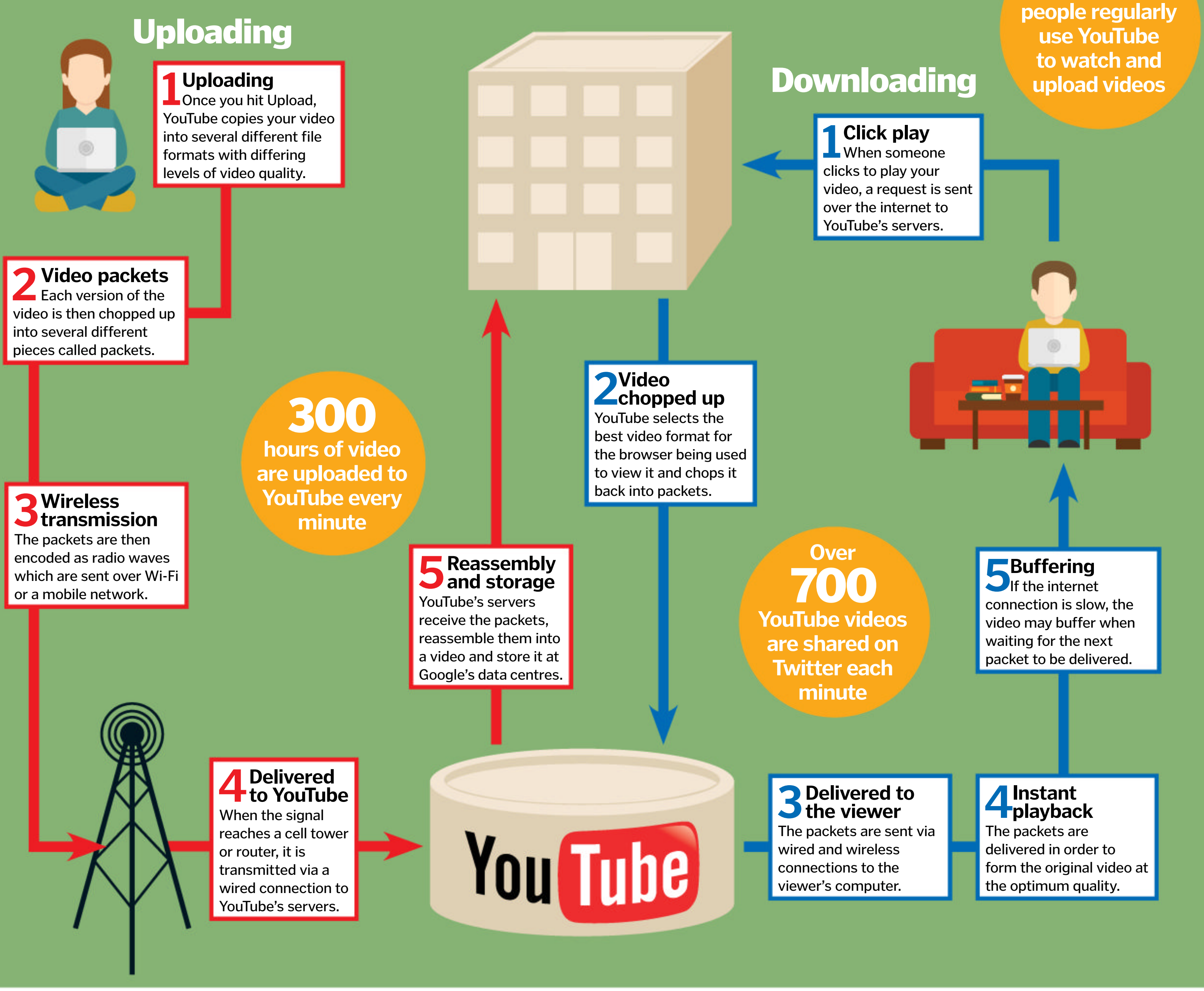
2007
YouTube Mobile is launched enabling people to watch videos on their smartphones, and the site begins showing adverts.

2008
720p HD support is added, enabling high definition videos to be uploaded and viewed widely for the very first time.

DID YOU KNOW? More video is added to YouTube in one month than the three main US television networks have made in 60 years

The journey of a YouTube video

What happens to your video once it has been uploaded?



Uploading

1 Uploading
Once you hit Upload, YouTube copies your video into several different file formats with differing levels of video quality.

2 Video packets
Each version of the video is then chopped up into several different pieces called packets.

3 Wireless transmission
The packets are then encoded as radio waves which are sent over Wi-Fi or a mobile network.

4 Delivered to YouTube
When the signal reaches a cell tower or router, it is transmitted via a wired connection to YouTube's servers.

5 Reassembly and storage
YouTube's servers receive the packets, reassemble them into a video and store it at Google's data centres.

Downloading

1 Click play
When someone clicks to play your video, a request is sent over the internet to YouTube's servers.

2 Video chopped up
YouTube selects the best video format for the browser being used to view it and chops it back into packets.

3 Delivered to the viewer
The packets are sent via wired and wireless connections to the viewer's computer.

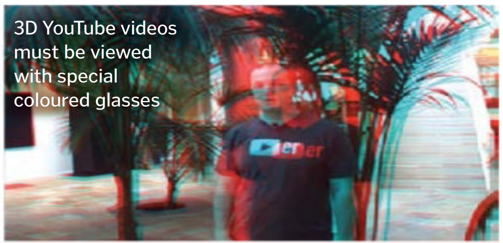
4 Instant playback
The packets are delivered in order to form the original video at the optimum quality.

5 Buffering
If the internet connection is slow, the video may buffer when waiting for the next packet to be delivered.

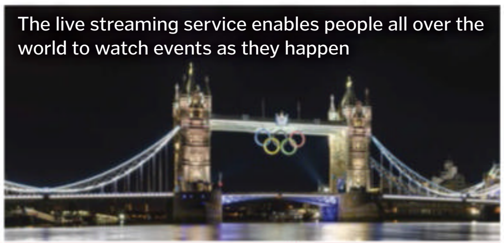
1 billion people regularly use YouTube to watch and upload videos

300 hours of video are uploaded to YouTube every minute

Over **700** YouTube videos are shared on Twitter each minute



3D YouTube videos must be viewed with special coloured glasses



The live streaming service enables people all over the world to watch events as they happen

Spherical videos can be used with VR headsets, offering users 360-degree panoramas

2009
Users can now upload and view up to 1080p HD footage. Support for 3D videos is also added for a better viewing experience.

2010
YouTube keeps up with technology and includes support for ultra-high definition 4K videos to be uploaded to the site.

2011
YouTube's Sliced Bread project enables videos to be sent to your device a little bit at a time to help prevent buffering.

2012
The live streaming service is improved, enabling over 1,200 events during the London 2012 Olympics to be watched live.

2014
Support for videos that play at 60 frames per second (fps) is added, which provides much smoother playback.

2015
Spherical videos can now be uploaded, enabling the viewer to see a scene from absolutely any angle of their choice.

© Rex Features; Thinkstock

Why is superglue so super?

This scanning electron microscope image shows superglue's adhesive surface close up

Find out how a square inch of superglue can support more than a ton

The compound responsible for superglue's characteristic sticky strength is called cyanoacrylate, which is an example of an acrylic resin. As soon as it is placed on a surface it cures (forms its strongest bond) in an almost instantaneous reaction, requiring only the presence of the hydroxyl ions found in water for this to happen. Nearly all surfaces we encounter have trace amounts of water, as it is present in the air we breathe. This process is an example of anionic polymerisation; the cyanoacrylate molecules link together in a mesh when they come into contact with water, creating a super-strong bond. This differs from the way white glues bond which is by solvent evaporation.

Other than sticking two materials together, superglue can be employed in a variety of other settings. In forensic science, it can be used to visualise latent (invisible) fingerprints, as the superglue's vapours bind to the moisture that is deposited by the fingerprint, turning them white and visible. This reaction also stabilises the fingerprint's detail, making it possible for further enhancement to be carried out. A non-toxic version of superglue has also been created for surgery which can be used to seal the skin without the need for sutures.

Turn ashes into diamonds

How high temperatures and pressures can convert our bodily carbon into cremation diamonds

Knowing how to commemorate a loved one's passing is incredibly difficult for us all, but there is now a wide range of alternatives to traditional burial or cremation. An alternative to sending your relatives' ashes into orbit, a technique has been devised to convert them into diamonds. A typical 80-kilogram (176-pound) man produces enough ashes to make a 0.2-gram (0.007-ounce) diamond, as our bodies are 18 per cent carbon.

To do this, the ashes are heated to over 2,760 degrees Celsius (5,000 degrees Fahrenheit) in a heat-proof crucible. This works to oxidise all of the elements within the ashes, other than the carbon. The carbon is then heated for a number of weeks to turn it into graphite, which is then pressed with a metal catalyst and a diamond-seed crystal. This step requires temperatures of around 1,371 degrees Celsius (2,500 degrees Fahrenheit), along with extremely high pressures, and needs several weeks to convert the graphite into a rough crystal.

This crystal can then be cut to specification and presented as desired by the client. The finished diamond's colour is typically a deep yellow or orange, depending on the amount of other trace elements within the original ashes. This can be changed by further enhancement techniques if you wish.

Cremation diamonds can cost as much as £13,400 ($20,000), depending on the colour and quality desired

© Rex Features

How sunglasses protect your eyes

The sight-saving secrets of a summer style staple

Reaching for our sunglasses on a bright, sunny day is second nature; we all know that spending time in the Sun puts us at risk of eye damage and no one enjoys a squinting-induced headache. Perhaps you take them for granted, but there's more to your sunnies than shaded lenses.

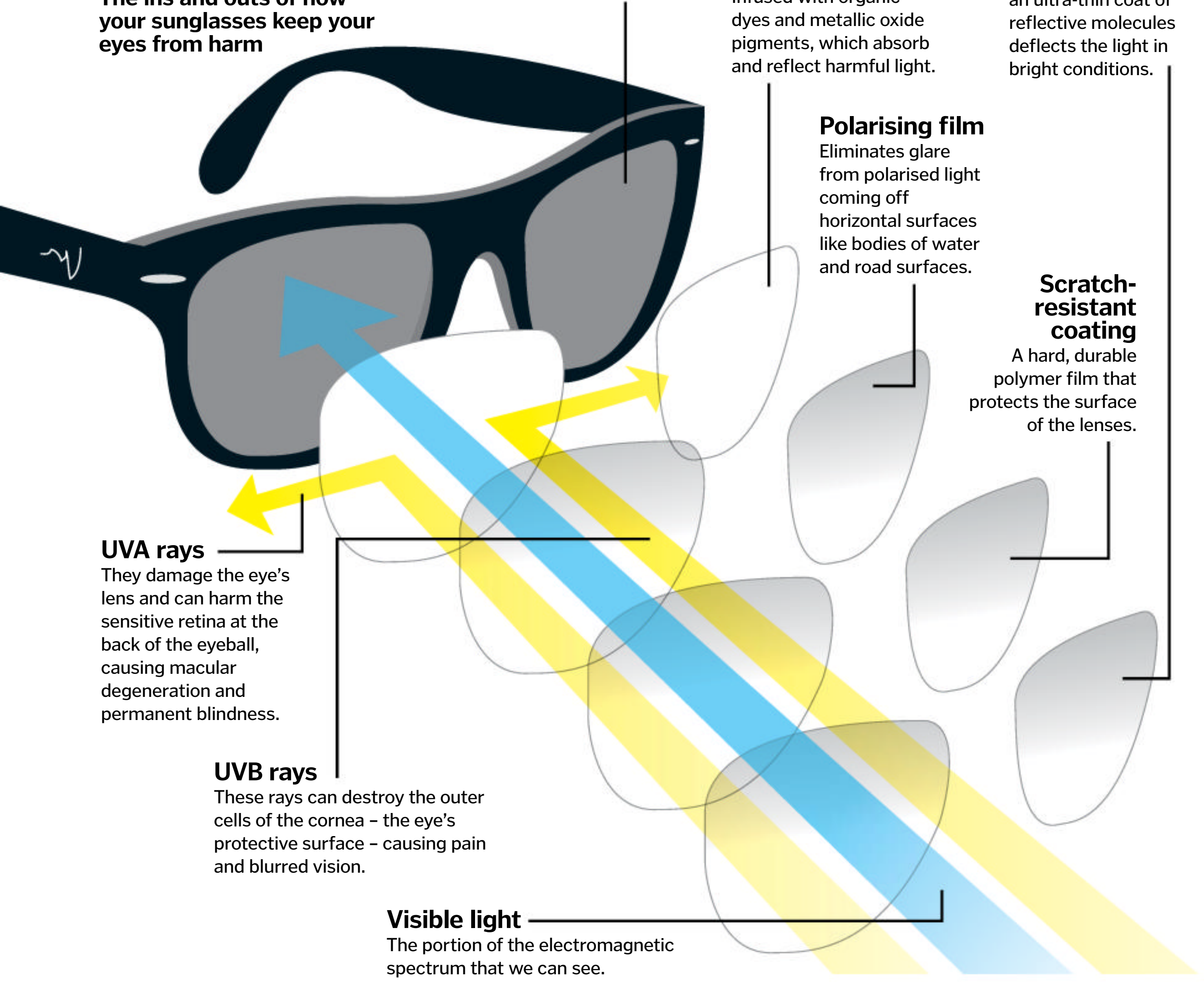
Aside from lending mere mortals an air of film star mystique, sunglasses' premier function is to block the Sun's harmful ultraviolet (UV) rays. There are two types of UV rays: UVA (which cause skin cancer and premature ageing) and UVB (responsible for sunburn). Both types have higher frequencies than the visible light our eyes can perceive. They damage our eyes the same way they damage our skin, except that even in the shade reflected rays pose a threat to our eyes.

Sunglass lenses are made from glass, plastic or polycarbonate, with a special UV-absorbing coating. A good pair blocks more than 99 per cent of UV radiation from reaching your eyes. Tints and mirror coatings relieve you from squinting, by absorbing or reflecting intense, dazzling light in the visible part of the spectrum (the light we can actually see).

The highest-grade sunglasses also incorporate a polarising film to combat glare from reflective horizontal surfaces like water, sand and snow. Light waves vibrate just like sound waves do. There's a mish-mash of horizontal and vertical components to these vibrations, but when light waves strike a uniform horizontal surface they are reflected with a strong, horizontal polarisation. The glare we experience is the jam of light waves all vibrating in the exact same plane. Sunglasses fitted with a polarisation film eliminate this kind of glare by only enabling vertically polarised light to pass through.

Safeguarding your vision

The ins and outs of how your sunglasses keep your eyes from harm



Anti-reflective coating
Sits closest to the eye and reduces back-glare and internal reflections off the lenses.

Lens (with UV coating)
Infused with organic dyes and metallic oxide pigments, which absorb and reflect harmful light.

Mirror coating
The first line of defence; an ultra-thin coat of reflective molecules deflects the light in bright conditions.

Polarising film
Eliminates glare from polarised light coming off horizontal surfaces like bodies of water and road surfaces.

Scratch-resistant coating
A hard, durable polymer film that protects the surface of the lenses.

UVA rays
They damage the eye's lens and can harm the sensitive retina at the back of the eyeball, causing macular degeneration and permanent blindness.

UVB rays
These rays can destroy the outer cells of the cornea – the eye's protective surface – causing pain and blurred vision.

Visible light
The portion of the electromagnetic spectrum that we can see.

Selecting your perfect pair

UV damage is cumulative, meaning it's never too early – or too late – to start protecting your eyes from the Sun. The most important thing is to choose sunglasses that offer 100 per cent UVA and UVB protection, just as you would with sunscreen. The larger the frames you pick out, and the more they hug your face, the less stray light will reach your eyes from around the edges.

Most people mistakenly believe that the darkness of the lenses is what protects their eyes. In fact, some clear transparent lenses can offer full UV protection, but those with a tint will cut out some portion of the light in the visible part of the spectrum too. Different tints offer various advantages – for example, ambers give sharp definition while greens reduce glare and increase contrast. Finally, if you intend to spend time on the water, beach or ski slopes – invest a bit more and up your protection level with polarising lenses.

Sunglasses with 100 per cent UVA and UVB protection are a must

© Thinkstock

Oculus
Development Kit 2

How the movie industry is poised to fight declining sales with virtual reality tech & more

THE FUTURE OF CINEMA

Over the last century, the film industry has grown exponentially from its humble beginnings, expanding across the globe to upward of 135,000 movie screens, and become an integral part of modern culture. But behind the scenes, all is not well. Anguished industry leaders are wringing their hands over a worrying new trend: people aren't going to the movies as much as they used to.

Box office revenues fell by five per cent between 2013 and 2014 in North America – declines that meant some of the country's premier cinema chains' profits plummeted by more than 50 per cent. The Motion Picture Association of America found that between 2012 and 2013, the number of 18-to-24-year-olds classed as 'frequent moviegoers' fell by 17 per cent, with the 12-to-17 age bracket dropping by 13 per cent. These groups have traditionally been relied upon to come through the doors week after week and empty their wallets over films and snacks.

For today's teenagers, the allure of the silver screen is just not what it was for their parents and grandparents. Gone are the days when the whole community would descend on the picturehouse of a Friday evening, eager to catch the latest release.

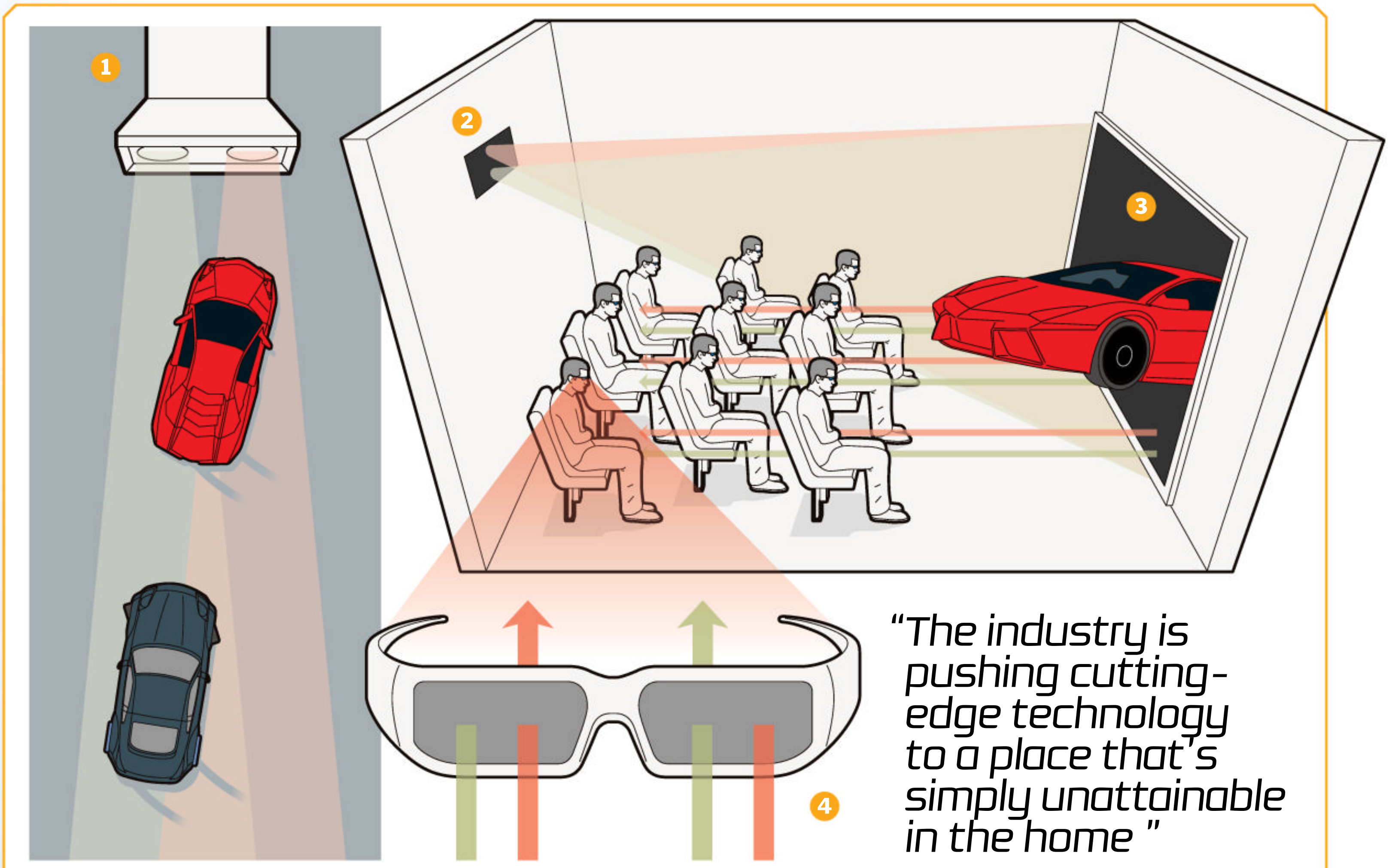
The ubiquity of smartphones, tablets and laptops, along with the proliferation of on-demand screening services, mean the next movie is seldom more than a couple of clicks away. In rich countries, families have the means to create convincingly cinematic experiences in the comfort of their own homes with huge flatscreens and surround sound systems.

But like any good action hero, the motion-picture industry is fighting back. On multiple fronts, creators are pushing cutting-edge cinema technology to a place that's simply unattainable in the home, to add extra facets to the moviegoing experience and motivate people to leave the house and head for the movie theatre.

One obvious tack is: bigger and better. Covering the bigger angle is IMAX – cinemas with giant, immersive, field-filling screens that swallow audiences into the action. After the technology was debuted during the 1970 world's fair, IMAX went public in 1994 and began its romance with Hollywood, pioneering a way to digitally remaster film for its humongous curved screens. Today, there are over 800 IMAX screens across the globe, many housed within traditional cinema multiplexes, and they're as popular as ever.

As for "better", the laser-projection revolution is now upon us. For almost 100 years, film projectors

DID YOU KNOW? *An IMAX projector weighs over 1,800kg (3,970lb) – the equivalent of a family car!*



> *"The industry is pushing cutting-edge technology to a place that's simply unattainable in the home"*

How RealD 3D works

RealD is the most widely used technology for watching 3D films at the cinema

1 Stereoscopic capture
The brain perceives depth and distance by merging images from each eye. In 3D filmmaking, special cameras capture two side-by-side images to simulate the perspectives of a viewer's left and right eye.

2 Sequential projection
Left and right eye images are beamed sequentially at a rate of 144 frames per second through a single digital projector, with each passing through a circularly polarising light filter of opposite handedness.

3 Silver screen
A special screen embedded with silver (or other metallic) dust perfectly maintains the polarisation of each image when it reflects the projected light back toward the audience.

4 Special specs
RealD glasses are fitted with a pair of oppositely handed circular polarisation filters, which allow each eye to view only its intended frames. This creates the impression of depth in the picture.

have used electric-arc lamps – first carbon, then xenon – as their light sources. In a traditional film projector, light passes through the 35-millimetre film and a magnifying lens to project the image onto the screen. Over the last decade or so, more and more cinemas have been switching to digital projectors as a way to cut costs and improve picture quality at the same time.

Digital projectors continue to use xenon arc lamps, but a series of prisms and filters splits it into its constituent colours – red, blue and green – and directs each at one of a trio of spatial light modulator (SLM) chips. These measure just a few centimetres across, but split the light into millions of tiny beams, one for each pixel in the frame, according to the digital movie file, before it passes through the projector optics.

The digital setup slashes distribution costs – hard drives are much easier to ship than bulky reels of film – and enables a pristine image to be projected over and over again without ever scratching or losing clarity. Today, over 80 per cent of the world's cinemas have converted to digital, but some film aficionados complain the format loses 35-millimetre film's rich contrasts between light and shadow.

Enter laser projectors. The new kid on the block – which made its commercial debut in 2012 – might finally be the holy grail of film projection. It works just like a digital projector, but uses individual red, blue and green laser light sources in place of the xenon lamp. Its pictures have unparalleled sharpness and superior colour range; finally something to rival the vibrancy and beauty of high-quality film stock. Not only that, but laser projectors also produce images about twice as bright as bulb projectors and are extremely efficient, potentially lasting for ten years in commercial use – a gigantic improvement on the operating life of a xenon bulb, which is typically between 500 and 2,000 hours.

Of course, improvements in lumens and contrasts may be all well and good for film connoisseurs, but they're unlikely to tempt the average 15-year-old through the door. To snare them, cinemas are looking to augment the experience of going to a film. Emerging 4D cinemas offer interactive encounters that blur the line between cinema and amusement park; 3D film technology is much improved, and ambitious studios like DreamWorks are even seriously pursuing futuristic plans to marry virtual reality with film.

The next five years are set to see the swiftest and most significant technological advances in the history of motion pictures, coming soon to a cinema near you!

© Thinkstock

How virtual reality will transform cinema

Step into your own private movie theatre, or even into the movie itself!

DreamWorks – the production company responsible for animation blockbusters like *Kung Fu Panda, Madagascar* and *How To Train Your Dragon* – is developing technology that will take audiences right into the heart of its fantastical worlds. Its innovative new format – dubbed 'Super Cinema' – expands the film frame from its current limited screen dimensions into a fully immersive 360-degree swathe, with the viewer at the centre. The idea is that when this is combined with virtual reality (VR) headsets such as Oculus Rift or Gear VR – special goggles that allow wearers to see simulated 3D worlds – viewers will be able to turn their gaze in any direction, to whichever part of the scene captures their attention.

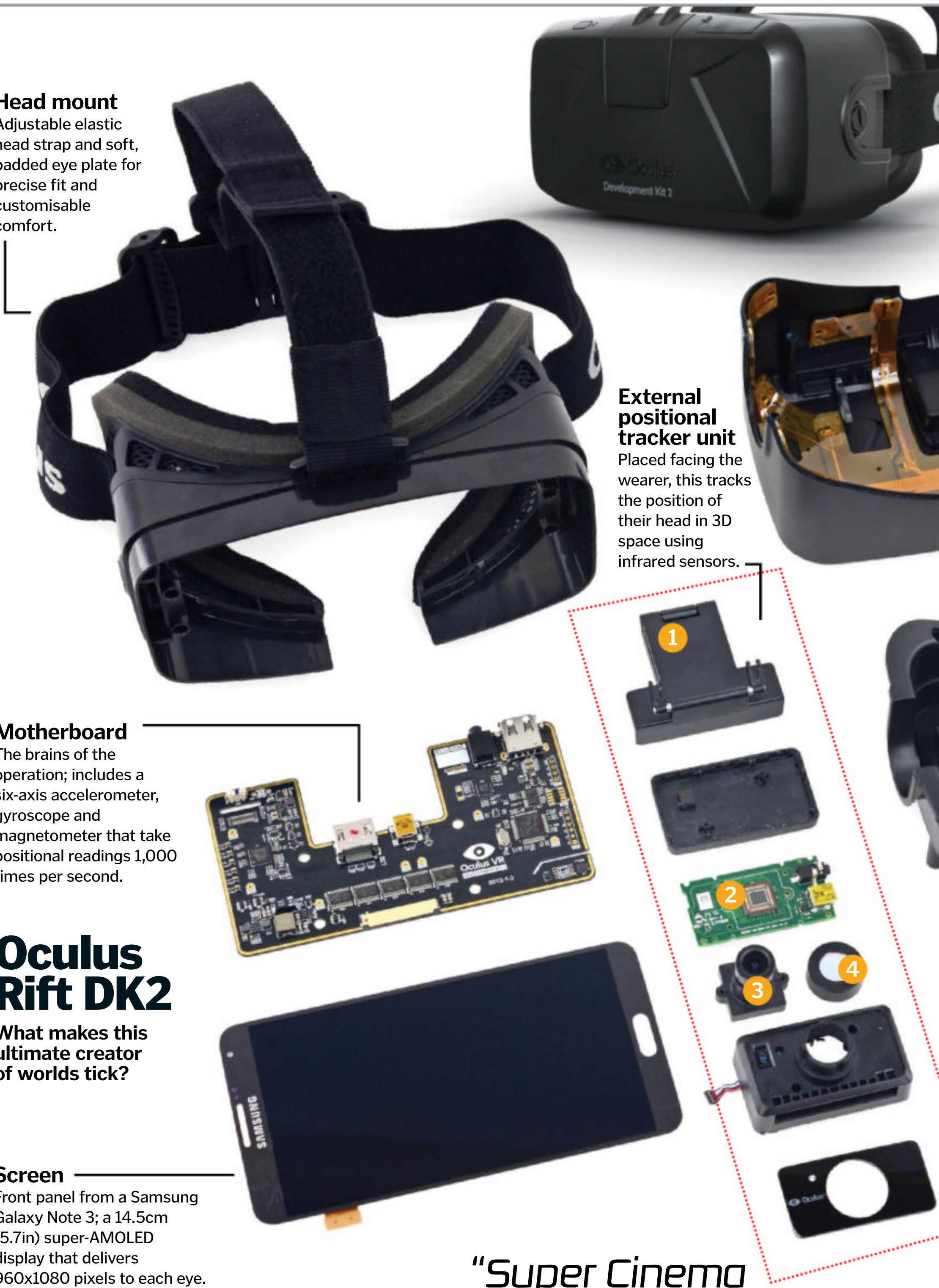
Computer graphics are created by one of two means – real-time rendering or pre-rendering. Real-time rendering is used heavily in other interactive experiences like videogames; the game decides which frame to draw depending on which way the player looks. Unfortunately, this is a time-consuming process, and with graphics as complex as today's CGI animations, this method would slow the frame rate to the point where the viewer start to see the still images switching or the film stalling altogether. Pre-rendering – where each possible view is already drawn and ready to load – makes the process significantly faster and the quality of the experience much smoother.

There are some downsides, though. Each 360-degree film would need to include all possible views of each frame, bumping up file sizes and production times astronomically. Super Cinema would also lack positional tracking – the ability to make minor geometrical adjustments to the image depending on how a person tilts their head – and wouldn't account for person-to-person variations in interpupillary distance (the distance between the eyes), which could make the film disorienting for some viewers.

Key to the success of Super Cinema will be a quality virtual-reality headset. Very few are actually available to consumers just yet, but the market looks set to be flooded with offerings in the next couple of years. Top of every technophile's wish list is the Oculus Rift, whose creators are also pursuing the idea of VR cinema, albeit a little differently. The most recent developer version of the headset runs a 'game' that allows wearers to recreate the moviegoing experience – including picking seats, looking around the theatre and watching the film on a huge screen in a choice of 2D and 3D – wherever the headset is worn – at home, on the bus or in class...

Oculus Rift DK2

What makes this ultimate creator of worlds tick?



Head mount Adjustable elastic head strap and soft, padded eye plate for precise fit and customisable comfort.

Motherboard The brains of the operation; includes a six-axis accelerometer, gyroscope and magnetometer that take positional readings 1,000 times per second.

Screen Front panel from a Samsung Galaxy Note 3; a 14.5cm (5.7in) super-AMOLED display that delivers 960x1080 pixels to each eye.

External positional tracker unit Placed facing the wearer, this tracks the position of their head in 3D space using infrared sensors.

> "Super Cinema expands the film frame into a fully immersive 360° swath"

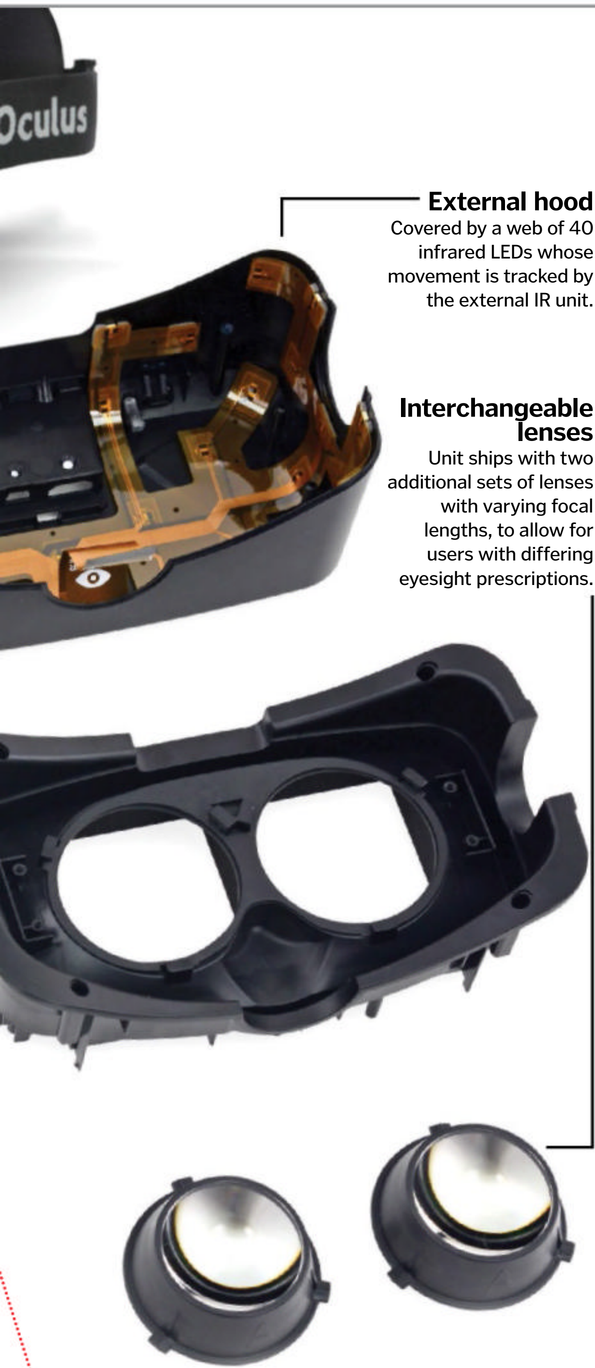
1 Tracker stand Articulated with several joints in order to get the perfect angle on the headset wearer.

2 Tracker control board Includes a CMOS image sensor, crystal oscillator and webcam controller.

3 Lens assembly Fitted with a wide-angle lens that allows the camera to see as much as possible of the headset at any time.

4 Infrared filter Allows only infrared light to enter into the camera.

DID YOU KNOW? *Facebook bought Oculus in 2014 for £1.3bn ($2bn), to bring the tech to medicine, education and communication*



External hood
Covered by a web of 40 infrared LEDs whose movement is tracked by the external IR unit.

Interchangeable lenses
Unit ships with two additional sets of lenses with varying focal lengths, to allow for users with differing eyesight prescriptions.

Beyond 3D:

Introducing the fourth dimension

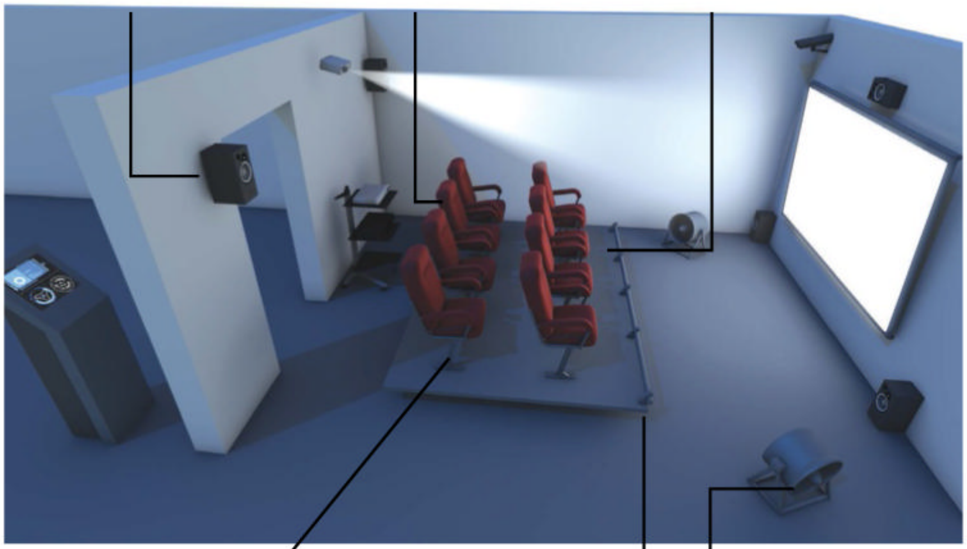
For those eager to feel even closer to the action, 4D cinemas combine the visual richness of 3D film with physical and tactile sensations – flashing lights, air jets, water sprays, scents, smoke, chair movements and more – that sync with and enhance the on-screen drama.

Seats are grouped in small clusters and a large air compressor located behind the auditorium drives their movements, which are pre-programmed, along with other effects, for each film. Some theatres are even touting experiences labelled '5D', '6D' and up, but unfortunately, that's little more than a marketing ploy – with each individual physical effect added to the screening being classed as its own extra 'dimension'.

Sound system
Standard 5.1 surround sound speaker system, augmented by ceiling speakers to offer directional "voice of god" moments.

Vibrating pads
Produce tactile sensations to heighten the drama – for example, a deep rumbling to accompany an avalanche beginning to roll.

Moveable racks
Can move chairs up and down, side to side and tip forward, backward and sideways to mirror the on-screen action.



Tickle stick
Activated by air jets in the chairs – designed to make audiences jump out of their skins during spider scenes!

Hall effects
Includes bubbles, mist, aromas, strobe lighting, and even fire!

Effects jets
Water and air jets intensify scenes with wind, rain, blood and guts, or speed.

How frame rate affects perception

When we watch a film, what our eyes actually see is a stream of still photographs switched so fast through the projector that our brain perceives them as one seamless motion picture, a bit like a hi-tech flipbook.

The threshold below which the brain is able to start perceiving individual images is 16 frames per second (fps), and the higher the frame rate, the more real the reel appears. With this in mind, the film industry grew up around a frame rate of 24fps as a way to balance production costs with painting reality convincingly on screen.

Today, big studios can afford to film movies at higher rates, ostensibly to offer their audiences a greater sense of immersion. But it turns out this can backfire. Peter Jackson's *The Hobbit* (2012) was filmed at 48fps and many people complained. After decades of conditioning, we've become accustomed to 24fps as an integral part of the 'cinematic' feeling, so audiences find hyperrealism disorienting, and a barrier to getting lost in the movie experience.

© iFixit; Pictorial Press Ltd / Alamy

Inside IMAX

Watching an IMAX movie is without question one of the most arresting film experiences in the world. Invented in Canada in 1970, by the end of 2013 there were 837 IMAX theatres in 57 countries across the world. Its defining feature is humongous screens – so large that the images completely fill the viewer's field of vision, giving them a feeling of immersion so strong that some even feel motion sickness during especially dynamic scenes!

IMAX technology

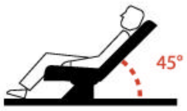
IMAX cinemas display gigantic images with incredible resolution, for a completely immersive experience

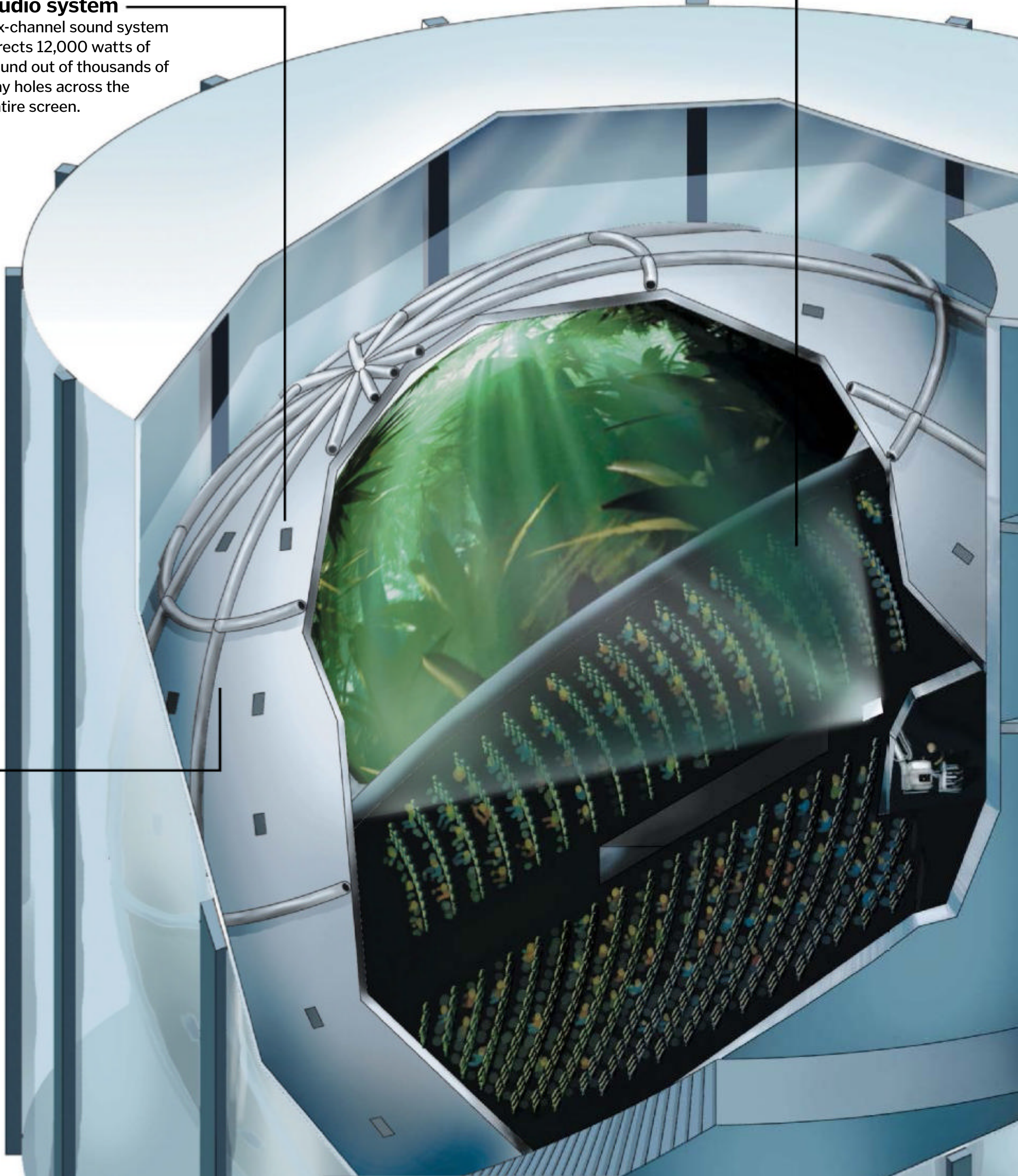
Audio system

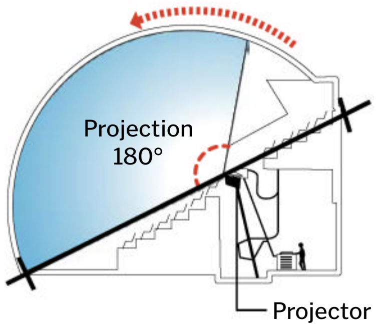
Six-channel sound system directs 12,000 watts of sound out of thousands of tiny holes across the entire screen.

Seating

Steeply racked so that even children's views are unobstructed, and people can gaze up and down as in real life.

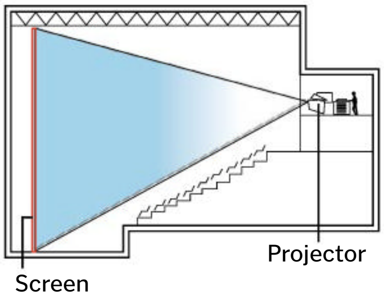





Projection
180°
Projector

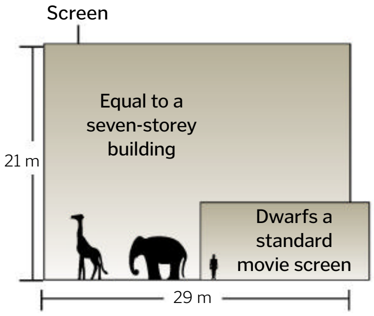
OMNIMAX dome

Hemispherical dome made of metal and coated with highly reflective white paint wraps the entire audience in larger-than-life images.


Projector
Screen

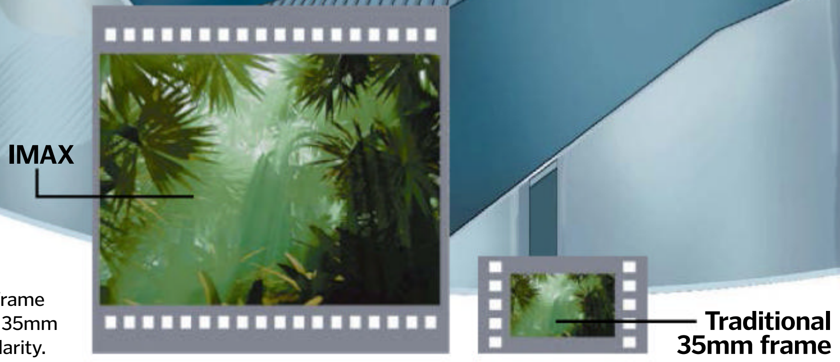
Flat IMAX

Uses a silver-coated flat screen that reflects light more intensely than a white screen.

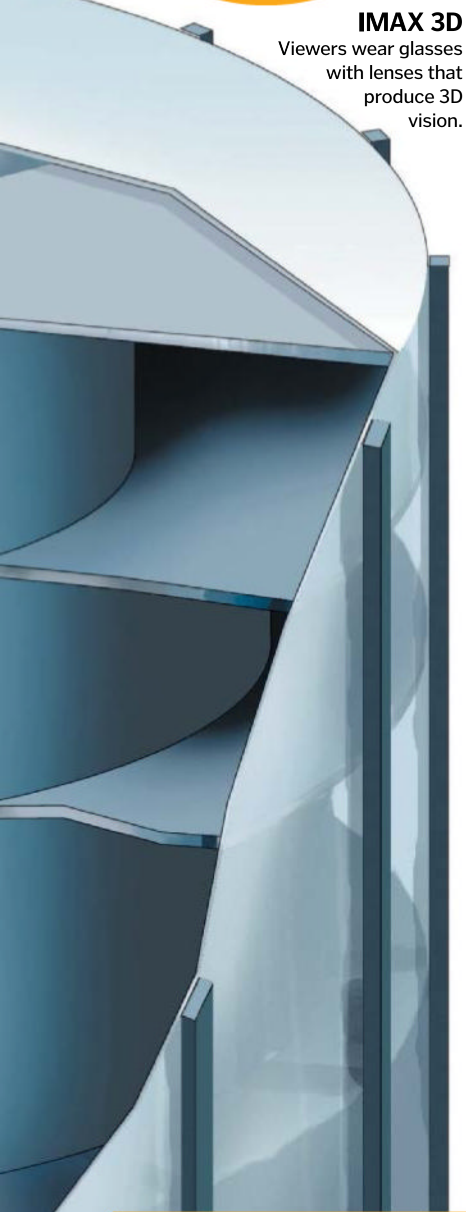

Screen
Equal to a seven-storey building
21 m
Dwarfs a standard movie screen
29 m

Film format

15/70 – 70mm (2.8in) film with 15 perforations per frame – results in a frame size about ten times that of standard 35mm film, giving IMAX movies incredible clarity.


IMAX
Traditional 35mm frame

IMAX 3D
Viewers wear glasses with lenses that produce 3D vision.

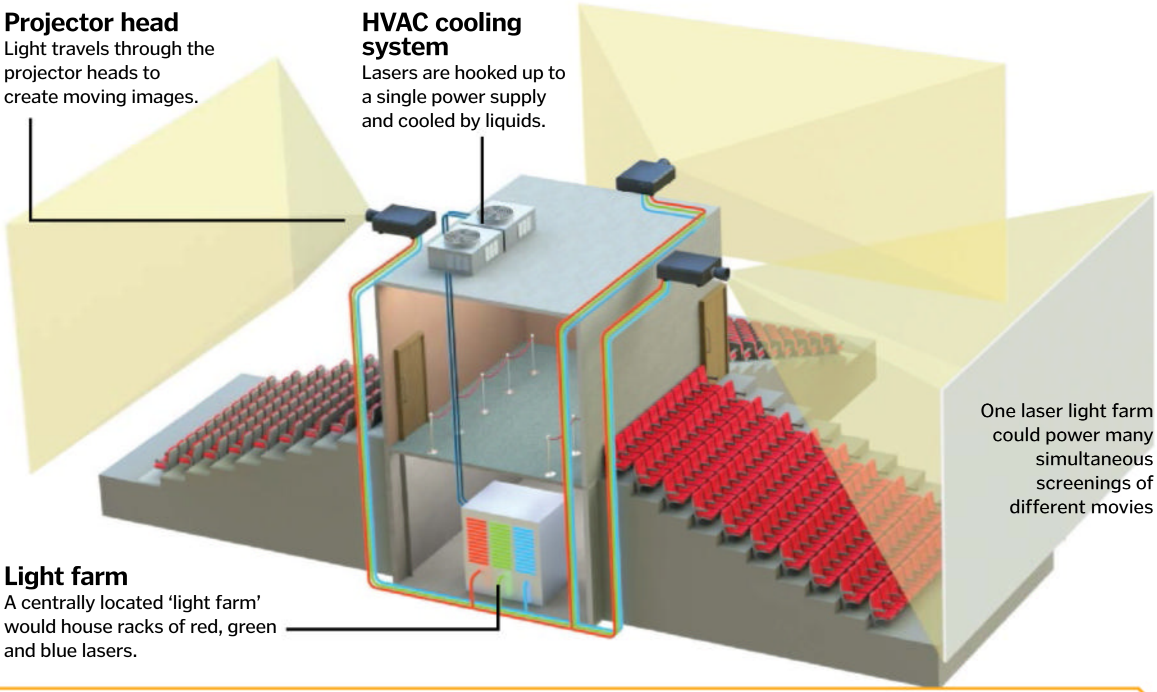


Laser multiplexes of the future

A switch from bulb projectors to laser projectors would open up the possibility of all the screens in a multiplex cinema being fed by one light source. A centrally located 'light farm' would host racks of high-powered red, green and blue lasers connected to a single power supply and cooled by liquids circulating from the cinema's rooftop HVAC system. Light would travel to each auditorium's projector head – fitted with the spatial light modulators and optics to create the moving images and focus them onto the screen – via armoured fibre-optic cables in the walls of the theatre.

In this setup, the laser light farm would be responsible for simultaneous screenings of different movies in each auditorium. The cinema's running costs could be dramatically reduced since there would no longer be a need for dedicated projection booths, and the projectors and light farm could even be controlled by off-site networked operators.

There is still no success in developing quieter popcorn for cinema



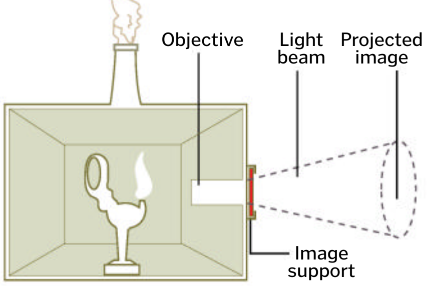
Projector head
Light travels through the projector heads to create moving images.

HVAC cooling system
Lasers are hooked up to a single power supply and cooled by liquids.

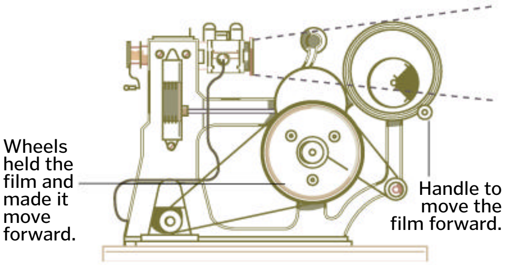
Light farm
A centrally located 'light farm' would house racks of red, green and blue lasers.

One laser light farm could power many simultaneous screenings of different movies

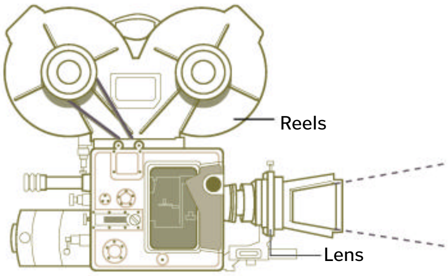
The first projection systems



Ca 17th century
The 'magic lantern' was the first system resembling modern projectors. They used candles or oil lanterns as light sources.


Wheels held the film and made it move forward.
Handle to move the film forward.

1895
The Lumière brothers invented a projector that took its mechanical inspiration from a sewing machine, and presented it in Paris.



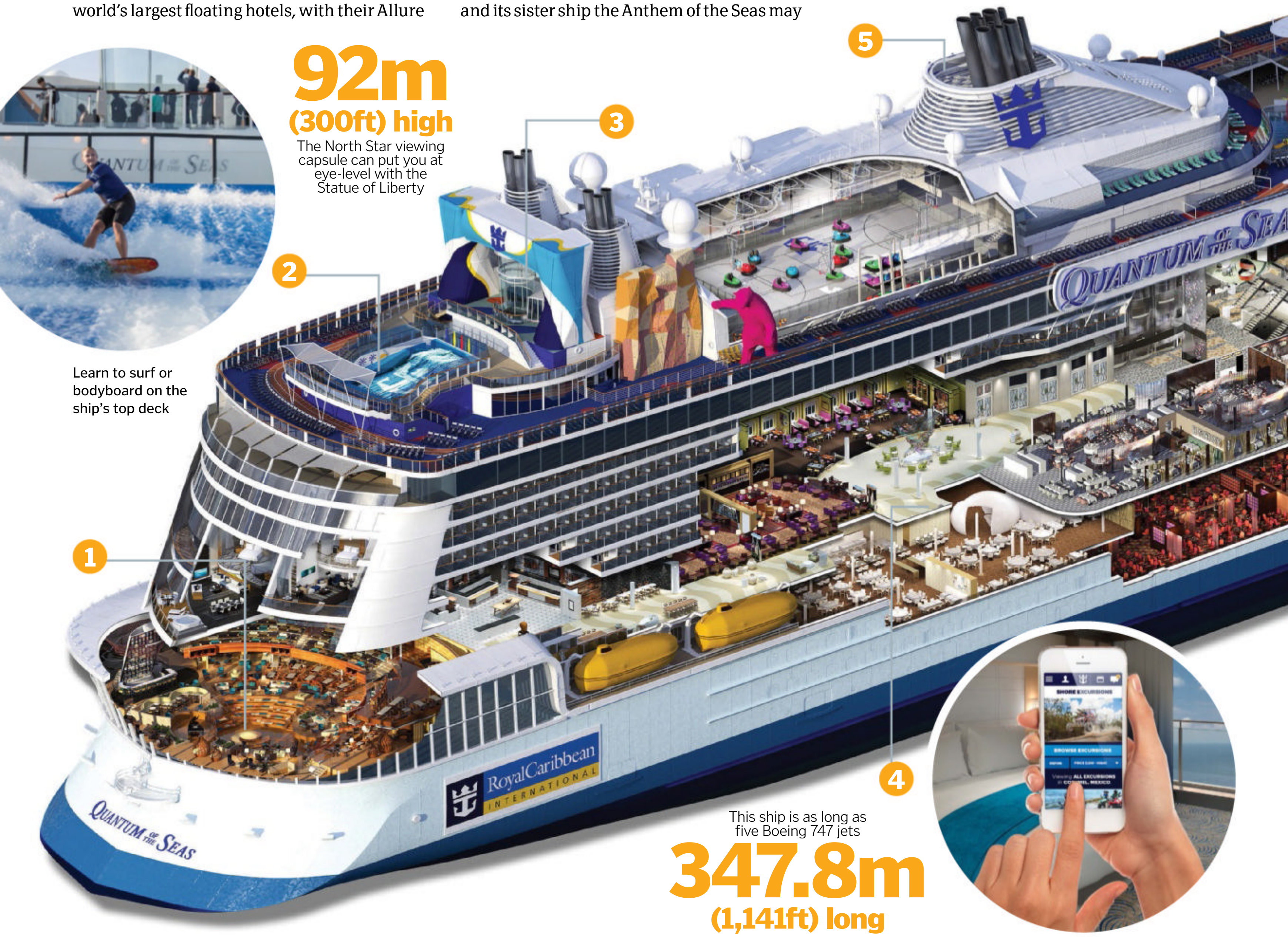
1932
The rise of colour cinema. Technicolor cameras superimpose three films in red, blue and green to deliver full-colour spectrum images.

© Solyo; Thinkstock

The ultimate cruise

Discover the amazing tech on board the latest colossal cruise ships

Cruise ships are getting bigger and bigger, with the latest vast vessels able to transport the entire population of a small town to new and exciting destinations. Cruise line Royal Caribbean International is leading the way when it comes to building the world's largest floating hotels, with their Allure of the Seas and Oasis of the Seas ships taking the top two spots. However, as well as making their ships bigger, they are also striving to make them smarter, with their latest vessels featuring state-of-the-art technology to enhance the cruising experience. The Quantum of the Seas and its sister ship the Anthem of the Seas may 'only' be the joint-third largest in the world, but it's the gadgets and gizmos on board that set them apart from the rest. With robotic bartenders, virtual balconies and a whole host of interactive art on board, these cruise ships offer the ideal holiday for tech fans.



92m (300ft) high
The North Star viewing capsule can put you at eye-level with the Statue of Liberty

Learn to surf or bodyboard on the ship's top deck

This ship is as long as five Boeing 747 jets
347.8m (1,141ft) long

1 Roboscreens

The large venue at the back of the ship is called Two70°, because its floor-to-ceiling glass walls offer 270-degree panoramic views. However, at night, the space is transformed as 18 projectors cast 12K resolution scenes onto the windows. Six 2.5-metre (eight-foot) 'Roboscreens' can also be choreographed to move independently or in unison to enhance the evening's shows.

2 Surf simulator

Test your surfing skills on board the ship with the FlowRider surfing simulator. This powerful machine pumps out 272,800 litres (72,057 gallons) of water per minute at speeds of 48-64 kilometres (35-40 miles) per hour, creating a smooth wave that you can surf or bodyboard, even when the surrounding ocean is as calm as a pond.

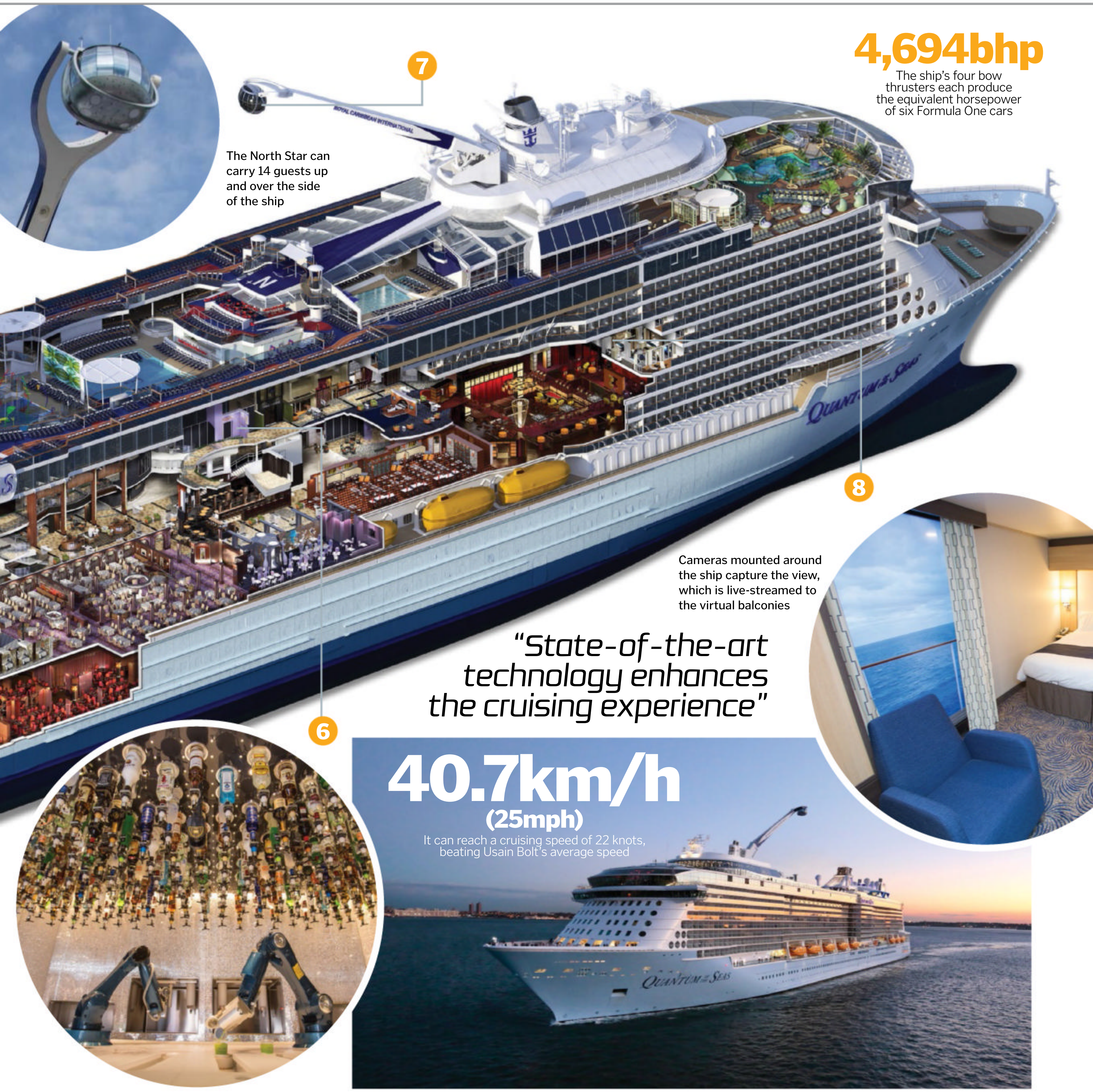
3 Skydiving simulator

The first skydiving simulator at sea enables you to experience freefall without having to jump out of a plane. The seven-metre (23-foot) tall vertical wind tunnel contains a fan capable of generating windspeeds of around 209-282 kilometres (130-175 miles) per hour, creating a cushion of air on which you can float.

4 App planner

When you climb on board, the free Royal iQ app enables you to track your luggage, so you know when it has been delivered to your cabin. It works by tracking the RFID (radio-frequency identification) tag on your bag, which uses electromagnetic fields to transmit data about your luggage's current location. The app also provides information about what activities you can do both on and off the ship.

DID YOU KNOW? *The Quantum of the Seas has a £3.3 million ($5.2 million) art collection with a 9.1m (30ft) tall 8-ton pink polar bear*



The North Star can carry 14 guests up and over the side of the ship

4,694bhp

The ship's four bow thrusters each produce the equivalent horsepower of six Formula One cars

Cameras mounted around the ship capture the view, which is live-streamed to the virtual balconies

> *"State-of-the-art technology enhances the cruising experience"*

40.7km/h

(25mph)

It can reach a cruising speed of 22 knots, beating Usain Bolt's average speed

5 Connectivity

Stay in touch with your friends and family back home with the super-fast internet on board. Satellites launched by tech company O3b Networks beam signals directly to the ship, delivering more bandwidth to the Quantum-class vessels than all the other cruise ship in the world combined. This enables you to upload photos, stream video and even compete with gamers all over the world in the Xbox Live suite.

6 Robot bar

Human bartenders have been replaced by robots at the high-tech Bionic Bar. You order your drink via an app on a tablet, choosing from the menu or creating your own concoction from a long list of ingredients. One of the two robot arms will then mix your drink, mimicking a human bartender's action to shake, stir or strain it.

7 Viewing capsule

You can get a breathtaking bird's-eye view of the ship and its surroundings by boarding the North Star viewing capsule. The glass pod is located on the end of a long arm fixed to the top deck. It can lift you 91 metres (300 feet) above sea level to give you a 360-degree view while at sea or in port.

8 Virtual balconies

Even if you can't afford to upgrade to an outside cabin with a balcony, you can still experience stunning views from your room. The interior cabins feature virtual balconies, using two-metre (80-inch) high-definition 4K LED screens to display the sights and sounds of the outside world in real-time.

© Royal Caribbean

How to fly a helicopter

Find out what it takes to fly these amazing aircraft

Piloting this piece of engineering is no mean feat. Immense mental and physical co-ordination is required; the ability to use each hand and foot independently to operate the flight controls is a prerequisite for any prospective pilot. This means training to become a pilot takes a significant amount of time and money. Typically more than 1,000 registered flying hours and numerous written exams are needed if you want to fly commercially.

Advancements in helicopter technology

A number of recent advancements have improved on the existing helicopter design. One of these is the no-tail rotor, or NOTAR. This functions to solve two commonly encountered problems; namely the noise made by the tail rotor and the ease with which it can be damaged.

It works by blowing spent air from the helicopter's main rotor down the tail boom. Slots located on the tail boom allow the air to escape, producing a sideways force that works to oppose the torque generated by the main rotor. By varying the amount of air expelled, this can also aid directional control.

A second engine is also being fitted to some helicopters, which functions as a fail-safe if the main engine were to stop working. Either engine is capable of keeping the aircraft airborne, enabling the pilot to land safely in the event of an engine malfunction.

This Belgian police helicopter features the innovative no-tail rotor (NOTAR) system

Inside the cockpit

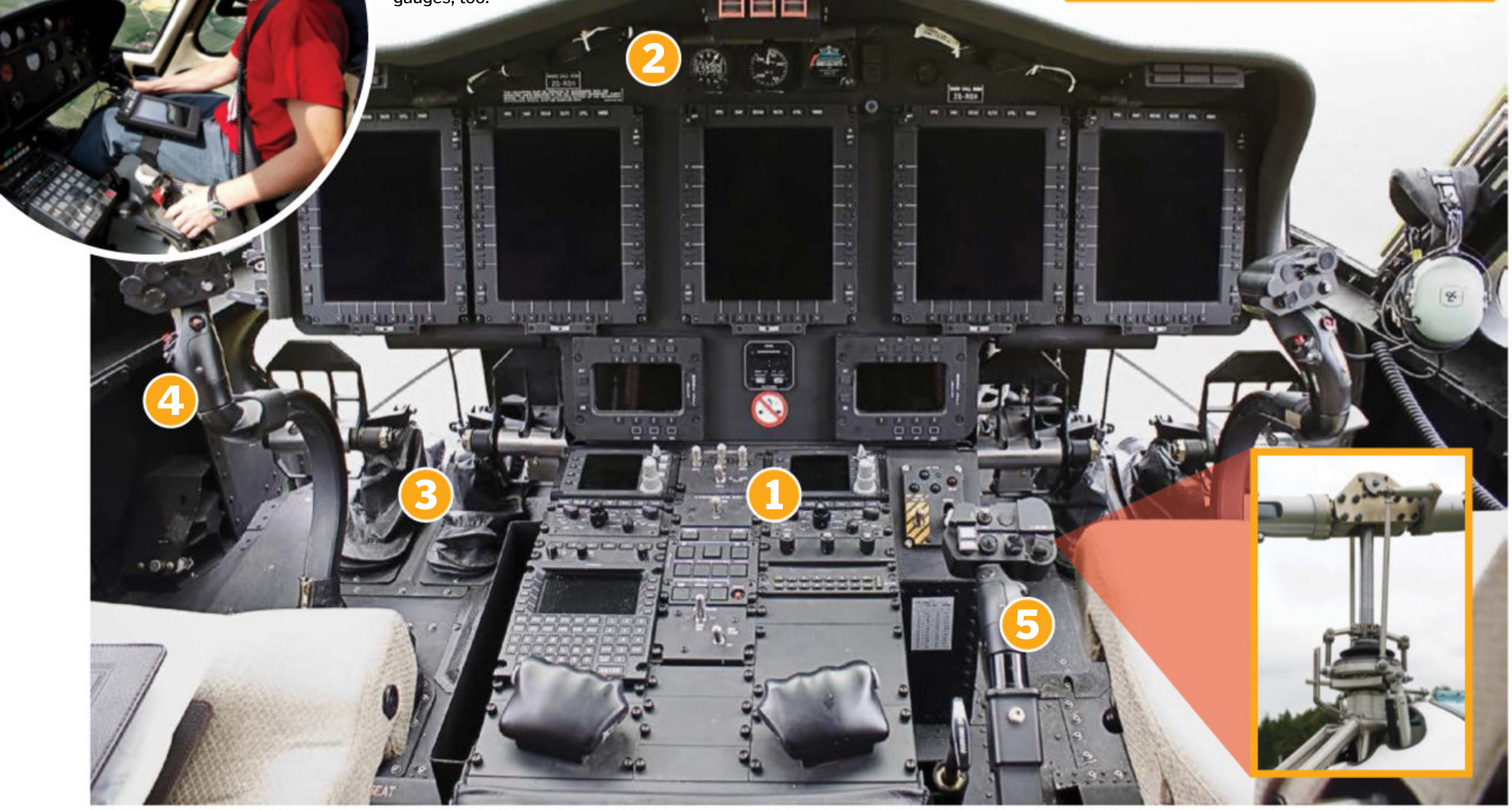
Learn how these controls enable a pilot to manoeuvre a helicopter

1 Centre console

The radio and transponder tend to be located on the centre console. A variety of other instrumentation will also be present, including master switches for the engine, and multiple temperature gauges, too.

2 Instrument panel

Similar to an aeroplane, there are a number of instruments that need constant monitoring while airborne, including speed indicators, as well as the altitude (height) and attitude (forward speed) values.



3 Anti-torque pedals

Located at the front of the cockpit are two pedals, which control the tail rotor. Operating the pedals causes a lateral change in direction, and is used to combat the torque created by the main rotors during takeoff, which causes the helicopter to turn.

4 Cyclic-pitch lever

Sitting between the pilot's legs, the cyclic-pitch lever works to tilt the aircraft forwards, backwards or side-to-side. It tilts the rotor disc in the desired direction of flight, changing the angle of the rotor blades to alter the helicopter's direction.

5 Collective-pitch lever

This works to move the aircraft up and down, and is used during the helicopter's takeoff. When engaged, a collective change is imparted on the pitch of all the aircraft's rotor blades, by changing the angle of the swashplate (inset image). The throttle is also located here, which controls the engine's power.

© Richair/Mikhail Starodubov/Patrick Allen/Dreamstime

DID YOU KNOW? *BMX racing a very new Olympic event, having made its debut at the 2008 Beijing Olympics*

New BMX technology

How tech taken from drones is helping BMX riders log their best times

Riders can immediately assess their performance after completing a lap of the track

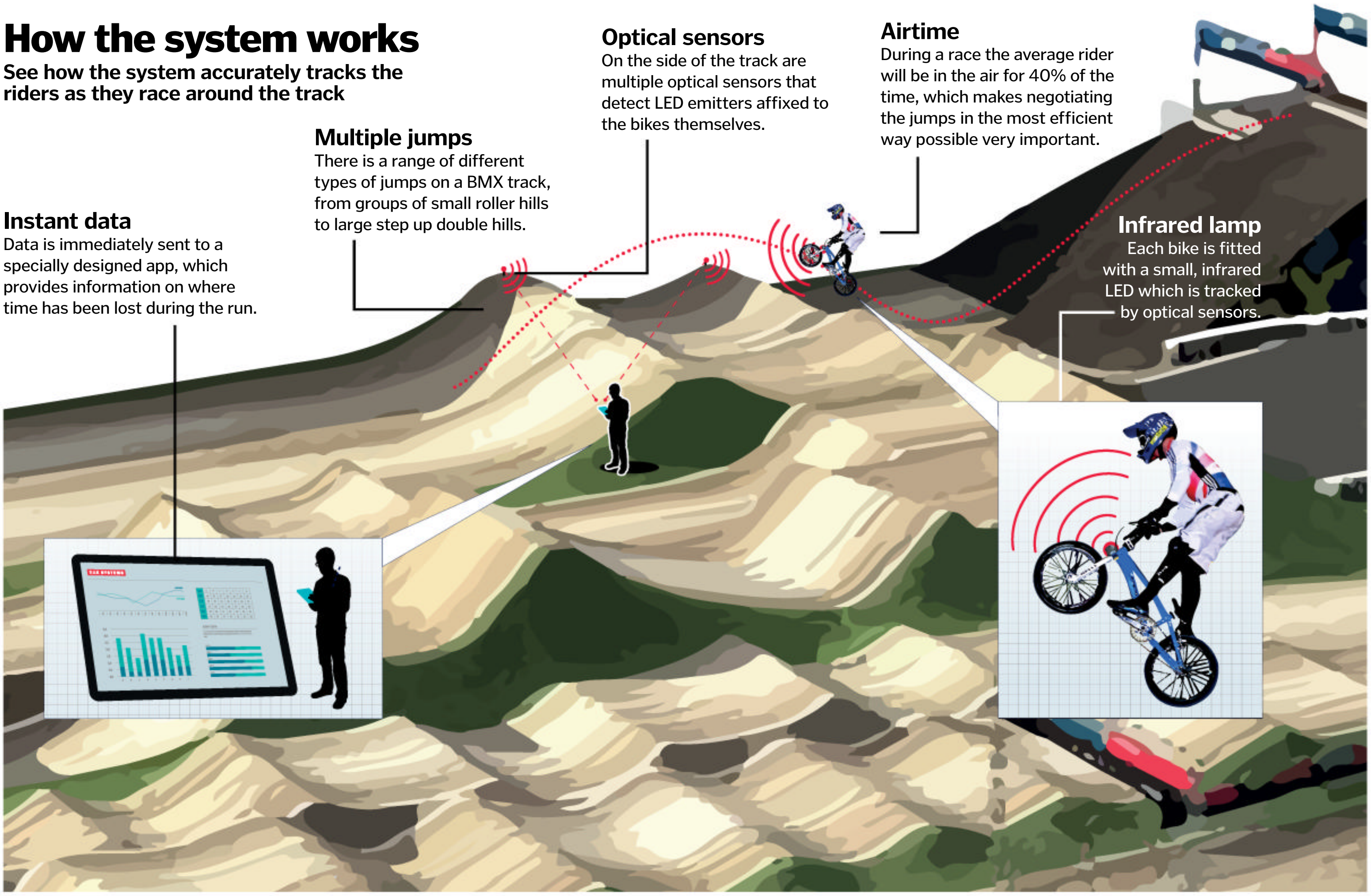
Ahead of the Olympics in Rio next year, Great Britain's BMX team are tirelessly training to give themselves the best chance of medalling. Every millisecond counts in events such as this, which has led the team to seek help from BAE Systems to see if their advanced tech can help them beat their personal best times.

BAE Systems offered a drone from their "sense and avoidance" system, which has been trialled as part of the Autonomous Systems Technology Related Airborne Evaluation & Assessment (ASTRAEA) programme, focusing on tracking objects in the sky. They adapted this technology to provide real-time data of a BMX rider's speed and trajectory, with more accuracy than had been possible before. The riders travel at high speeds during the race, in the region of 40 kilometres (25 miles) per hour. Maintaining these high speeds for as long as possible is vital; it's hoped that the precision of this technology will enable the riders and coaches to see exactly where time and speed is being lost.

The data collated during each run can be used to compare different riders with one another, which can identify what each rider does well and where they could make marginal gains. Prior to the use of this technology, only the overall time of the run was used. Now, the riders are able to review how their speed fluctuates during the run, especially over the multiple jumps.

How the system works

See how the system accurately tracks the riders as they race around the track



Instant data
Data is immediately sent to a specially designed app, which provides information on where time has been lost during the run.

Multiple jumps
There is a range of different types of jumps on a BMX track, from groups of small roller hills to large step up double hills.

Optical sensors
On the side of the track are multiple optical sensors that detect LED emitters affixed to the bikes themselves.

Airtime
During a race the average rider will be in the air for 40% of the time, which makes negotiating the jumps in the most efficient way possible very important.

Infrared lamp
Each bike is fitted with a small, infrared LED which is tracked by optical sensors.

© BAE Systems

The science of racing simulators

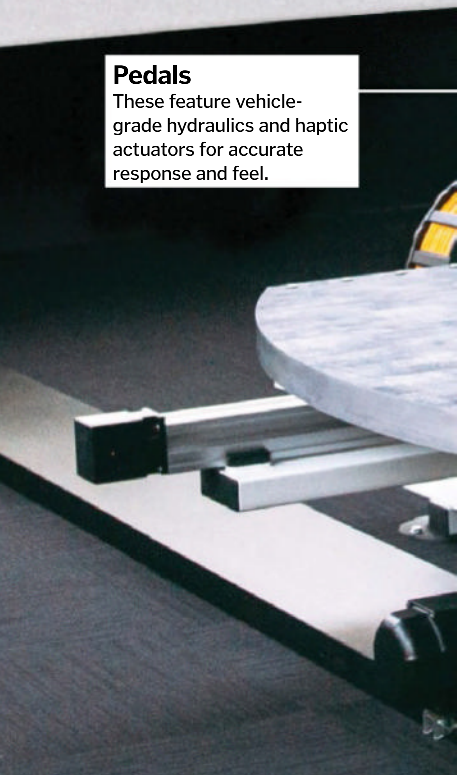
Almost as good as the real thing, these high-tech simulators are an invaluable training tool for a racing driver

We have all played on driving simulators in arcades or on games consoles at home, but what was once a bit of fun is now a serious business – and a crucial part of a professional racing driver's preparation for a competition.

The science behind these sophisticated modern-day race simulators lies within the human vestibular system, which comprises the small canals and bones in the inner ear. The utricle and saccule organs in the vestibular system help humans detect linear acceleration in three directions: vertical (for example, gravity), lateral (sway), and longitudinal (surges forward or backwards). In addition, three fluid-filled semi-circular canals are oriented in three planes to sense yaw, pitch and roll. As a person's body is moved about, tiny hair cells in the vestibule and semi-circular canals stimulate the vestibular nerve, helping the brain to interpret nerve impulses resulting from these six primary movements.

This is where the genius of new driving simulators come in: the movements of the simulator are designed to arouse a driver's vestibular nerves, creating a driving experience that's more true-to-life. As well as a real and working dashboard, the simulator is fitted with pedals that are hydraulically weighted the same as the car they're testing, and it's the same for the power steering 'feel' too. As for the graphics, they are displayed on a huge eight-metre (26-foot) screen and have a projection and resolution rate five times faster than that of a multiplex cinema, offering razor-sharp and, crucially, time-accurate images of the circuit that is being tested.

This all means simulators are a great way to get much needed practice on a circuit ahead of a race – particularly if it's a track that the driver has never visited before – and all done in familiar surroundings despite never actually sitting in a car. The accuracy of the facility means that time spent in the simulator is very nearly as good as doing the time in the cockpit itself, ensuring that the driver can enter a race buoyed by as much experience behind the wheel as possible.



Pedals
These feature vehicle-grade hydraulics and haptic actuators for accurate response and feel.

The lifestyle of a pro racing driver

You may think there's little else to the job of a professional racing driver than simply pulling up to the starting line and completing numerous laps of a circuit, but as Porsche's World Endurance Championship driver Nick Tandy tells us, you have to be 'race fit' to be able to pilot a modern race car.

With cars even more powerful and capable of pulling high g-forces through every twist and turn of a race, the driver needs to be mentally and physically fit enough to handle these constraints on the body, particularly in an endurance race such as the Le Mans 24 Hours.

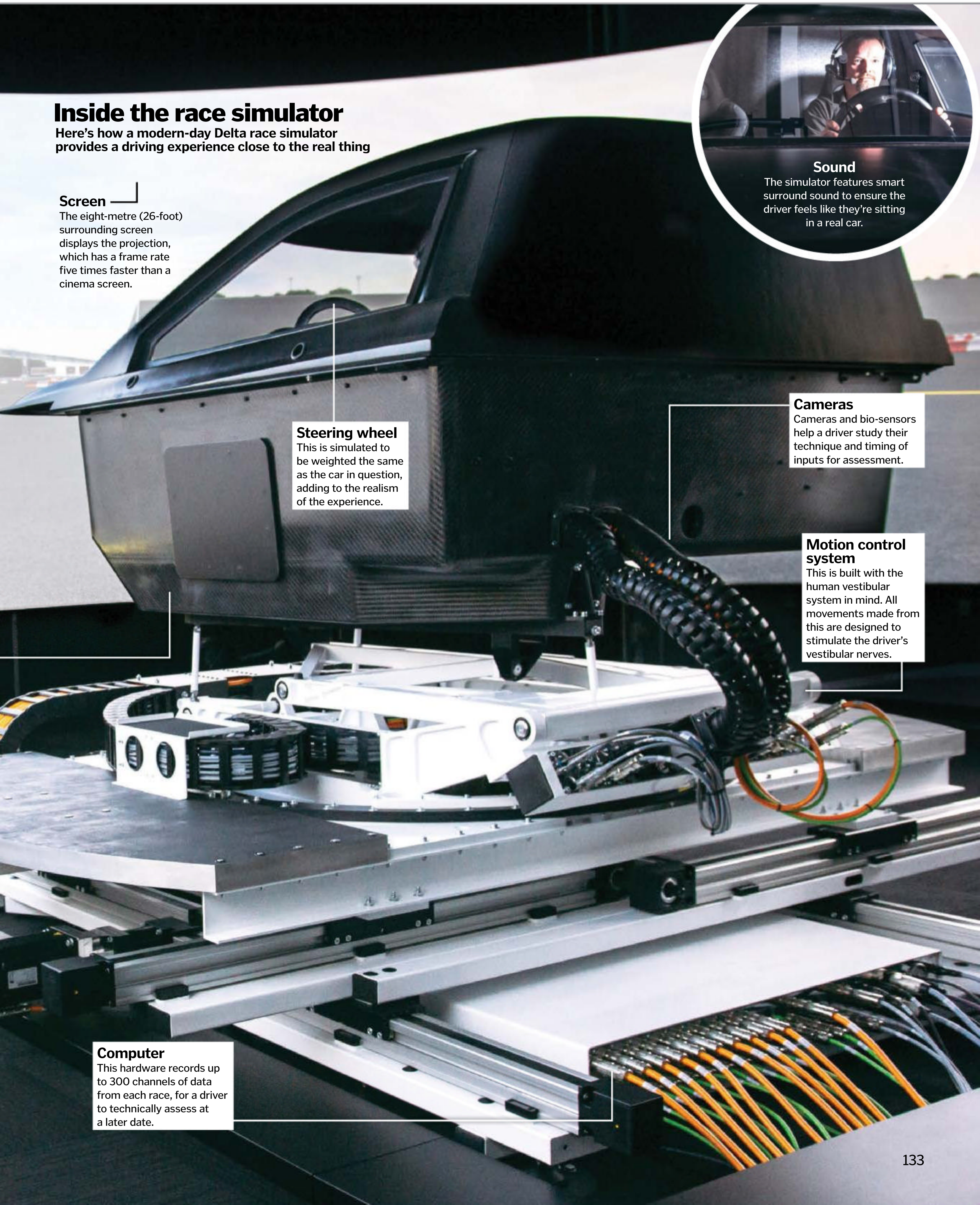
As such, pro drivers have intense fitness regimes and strict diet plans, with performance training to help improve reaction times and their acclimatisation to extreme heat. It doesn't end there, either: tactics are an important part of professional racing and drivers work hard to be attuned to the best setups of their car and driving style in all conditions, during every stage of a race.

Drivers need to be physically fit to withstand intense forces on the track

DID YOU KNOW? *Jann Mardenborough secured a racing contract with Nissan after winning a PlayStation competition*

Inside the race simulator

Here's how a modern-day Delta race simulator provides a driving experience close to the real thing



Screen
The eight-metre (26-foot) surrounding screen displays the projection, which has a frame rate five times faster than a cinema screen.

Sound
The simulator features smart surround sound to ensure the driver feels like they're sitting in a real car.

Steering wheel
This is simulated to be weighted the same as the car in question, adding to the realism of the experience.

Cameras
Cameras and bio-sensors help a driver study their technique and timing of inputs for assessment.

Motion control system
This is built with the human vestibular system in mind. All movements made from this are designed to stimulate the driver's vestibular nerves.

Computer
This hardware records up to 300 channels of data from each race, for a driver to technically assess at a later date.

ENGINEERING

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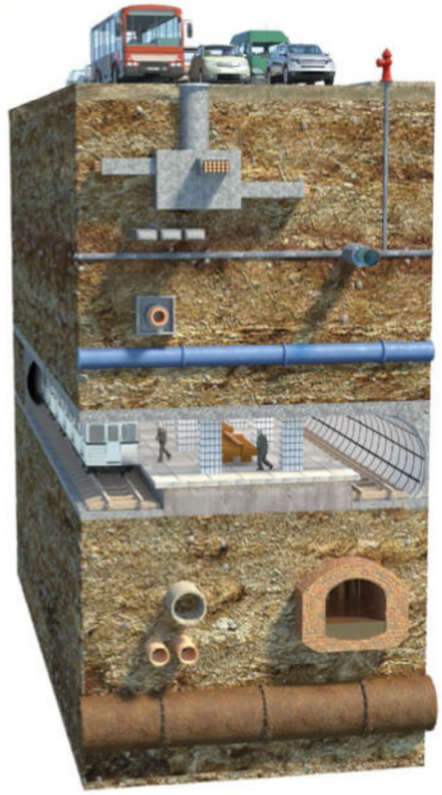
Racecars



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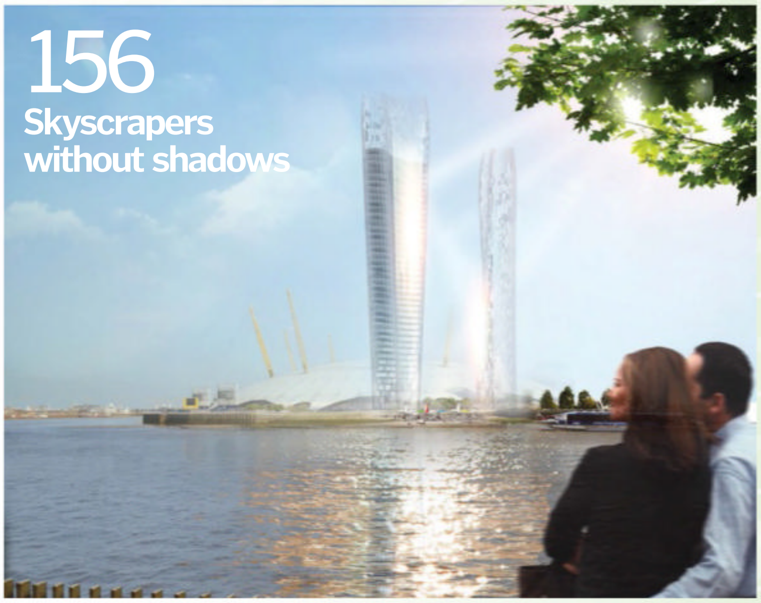

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ROAD CAR TO RACECAR

How normal, road-going cars are transformed into racetrack titans

In our contemporary world, the motor vehicle makes for a common sight on the public road. This is for good reason: there are currently more than one billion cars on Earth, helping us execute both short and long distance journeys in a variety of styles, be it in the name of luxury, practicality or simply pleasure.

However, aside from its ability to provide a form of travel to the masses, there is another facet to the role of the motor vehicle in society. Part of a culture that has existed ever since the birth of the car itself; as long as cars have been made, they've been raced, in various sporting disciplines. One of the earliest events was the Paris-Rouen contest in 1894, where cars travelled the 126 kilometres (78 miles) between the two French cities. As motoring developed, so did motorsport, giving rise to other championships such as Formula One in 1950, and touring cars in 1987.

As motorsport has evolved, so too have the cars that compete in its various forms, and many manufacturer-backed vehicles now take to the start line under a wholly different appearance from what we might see on the road. This is because a mass-produced vehicle in road-going form is designed for general use around the world. The majority of features, such as a comfortable ride or air conditioning, are not needed for motorsport, and so begins a monumental upheaval of the humble production car – usually right back to its bare shell – all in the name of triumphing once that chequered flag falls.

The result is a vehicle that's far removed from the 'jack of all trades' production car. The sums of money involved in the transformation are huge, and sponsorship deals are incredibly important for providing the requisite funding. Motorsport is a lucrative business, though, which is why nearly all major motoring manufacturers compete in at least one event. After all, it's the best shop window for your product, with most companies adopting a 'win on Sunday, sell on Monday' mentality, referring to the potential increase in car sales thanks to a race win the previous weekend. The changes, then, are very much worth it.

Body
Steel and alloy panels are replaced with fibreglass to reduce weight. The windscreen remains as glass but all other windows are plastic.

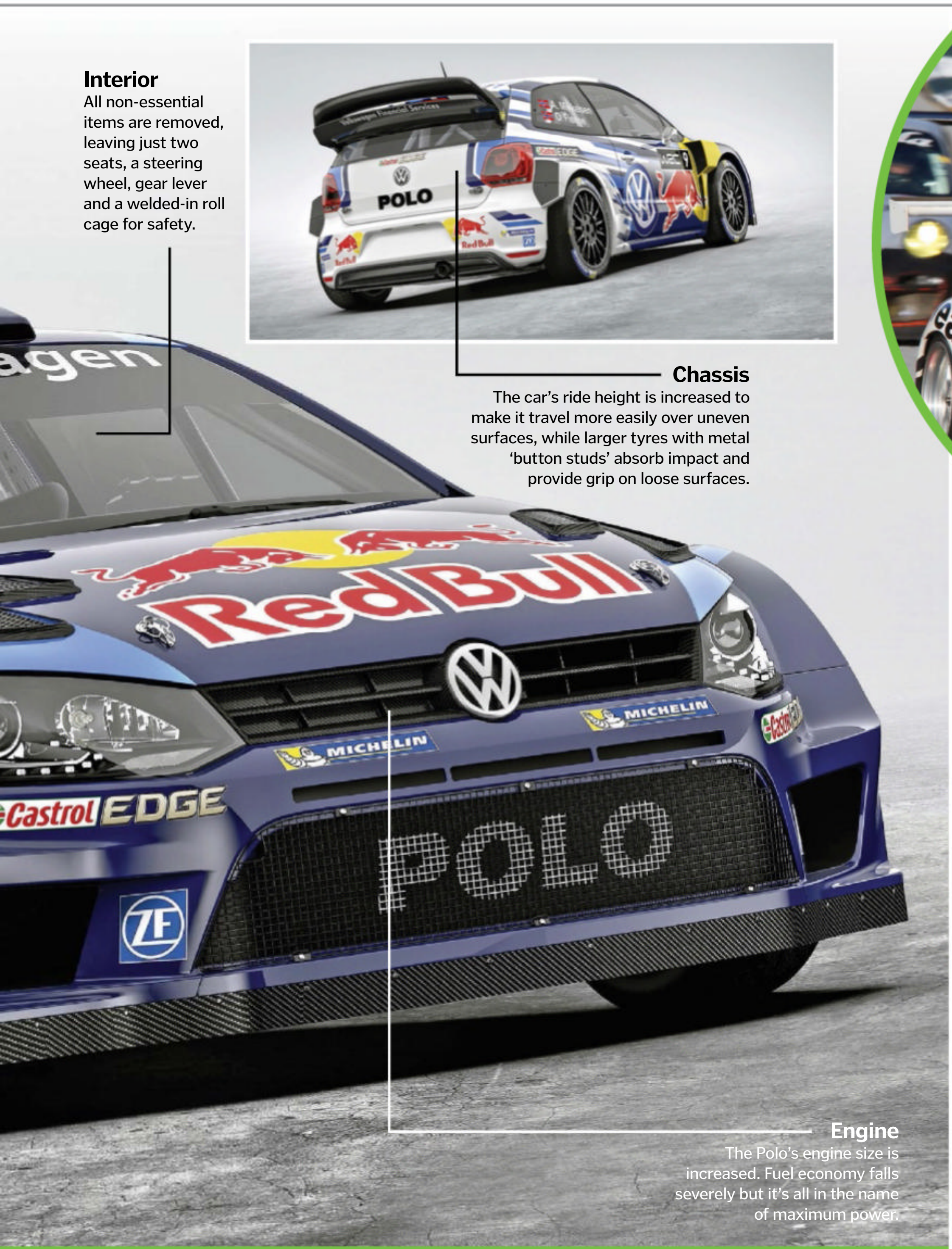
Rallying

In a sport as wild as the terrain it graces, a rally car must be specially prepared for its many challenges

Rallying is a race against time. Only one car takes on a rally stage at any one time, with recorded timings forming a league table as drivers jostle for positions on the leaderboard. Rally stages are usually held off-road and on rough terrain, and so a competitive car must be able to travel over the uneven landscape, and quickly. To ensure this is possible, manufacturers select a road car that is small and nimble, with a lightweight and short wheelbase, helping it to change direction quickly and fit through even the tightest paths in forests. Volkswagen, for example, utilise their Polo, a three-door hatchback model.

To transform it into a competition-ready machine, Volkswagen removes any unnecessary equipment: the rear seats, carpets, stereo and speakers are all scrapped to reduce weight. Then the car is strengthened to help withstand any shunts and bumps: a full roll cage is welded into the car, while a higher, long-travel suspension is fitted to ensure the car has plenty of ground clearance and can absorb any prominent bumps in the uneven surface. The engine is tuned for added performance and, unlike most motorsports, two seats are needed in the front rather than one, to accommodate the co-driver.

DID YOU KNOW? *Tyres used in professional drifting races are often road-legal items, but they're not fit for road use afterwards!*



Interior
All non-essential items are removed, leaving just two seats, a steering wheel, gear lever and a welded-in roll cage for safety.

Chassis
The car's ride height is increased to make it travel more easily over uneven surfaces, while larger tyres with metal 'button studs' absorb impact and provide grip on loose surfaces.

Engine
The Polo's engine size is increased. Fuel economy falls severely but it's all in the name of maximum power.

Before

Body
Steel body panels with smooth edges and subtle body profiling provide safety and style. Windows are glass, with the rear windscreen being heated.

Interior
The Polo seats up to five people, and includes air conditioning, heated seating as well as satellite navigation.

Engine
A small, quiet engine is used, which is economical to run and relatively easy to repair.

Tyres
Rubber tyres with a 7mm (0.28in) tread depth are part of a chassis setup aimed at providing comfort to the car's occupants on tarmac road surfaces.

Drifting

A sport dedicated to sliding means substantial revisions for this tyre-shredding spectacular

Smoking, screeching tyres and a wayward rear end may portray a picture of a car that's out of control, but drifting is a dark art that arguably represents the zenith in high-speed car control from a driver. Although boasting a huge following in America, drifting is a relatively new phenomenon in the UK. This discipline is all about grip, where big slides are worth big points around a track or specially mapped course.

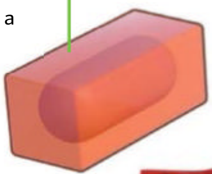
In preparation for a life going sideways, drift cars are lowered to the floor to reduce body roll, and stiffened with anti-roll bars – perfect for flicking that rear end out quickly. A strengthened hydraulic handbrake with a bigger, easily accessible lever is installed, as a driver will use this regularly to lock the rear wheels to help start a slide. The car's steering is also revised to ensure the front wheels can have up to 60 degrees of lock, giving the driver added manoeuverability. A 700bhp engine is fitted along with an all-important limited slip differential to ensure big slides, while long-lasting tyres are essential to ensure the car can remain competitive for as long as possible, even through all that burning of rubber!

A drift car exerts huge power for big speeds, while a refined chassis ensures precision power slides

Modifications

A behind-the-scenes look at the transformation process

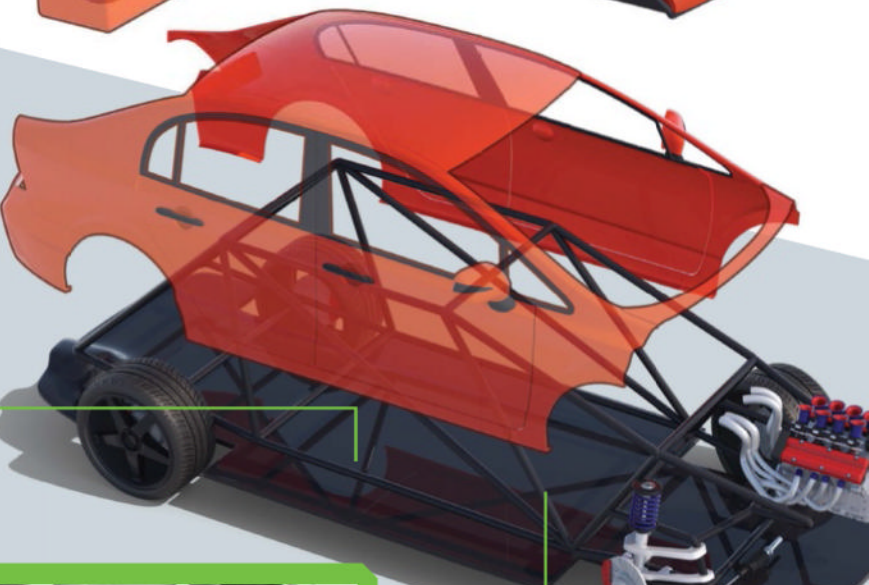
Unlike the build of a mass-produced car – which takes place on a production line and is usually carried out by robots – the transformation to a race car is usually done by hand in small, highly-trained teams. The work isn't over once the build is complete, either. Tinkering is often done to adjust the car after practices, to ensure even the smallest of gains over rivals, and it's common for a race car's engine to be taken out, stripped down and completely rebuilt after each race weekend, too. This is because an engine's components are placed under extreme strain for long periods of time during a race, and letting them deteriorate could affect performance later in the season.



Fuel tank
A larger fuel tank is usually fitted; it is likely to be an alloy fuel tank instead of a plastic one to make it more durable for racing.

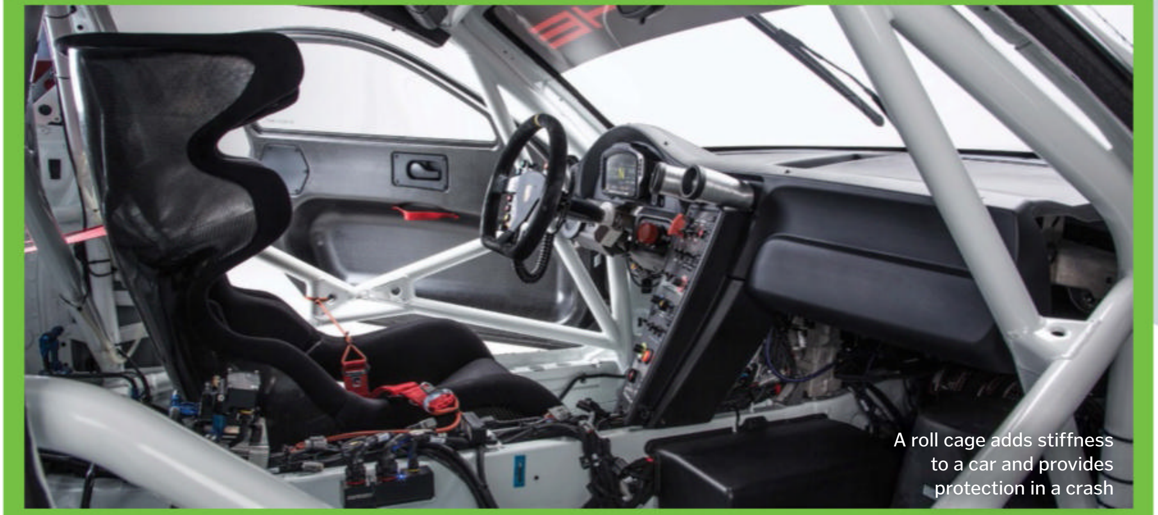
Driver's seat
Cars in motorsport will almost always swap a luxury leather chair for a bucket seat.

Standard road car
A typical road-going vehicle is a start base for a motorsport car. Though the interior may change, the roof and some body panels stay the same.



Weight saving
Everything not essential for racing is removed from the inside of the car, saving on weight. This improves the car's power-to-weight ratio.

Roll cage
With the interior stripped, a roll cage is welded or bolted in, protecting the driver should the car roll onto its roof.



A roll cage adds stiffness to a car and provides protection in a crash

Roll cage: A vital safety device

Commonly found inside competitive cars, a roll cage is usually a mandatory safety component. It is designed to protect the occupants inside of a vehicle in the event of it rolling over, stopping the car from flattening. A roll cage looks like a large metal frame inside the passenger compartment of a car, stretching from floor to ceiling and, usually, from front to back. This large frame effectively shields the driver, so that in the event of an accident, the car doesn't crumple in on them with nasty – and potentially fatal – consequences. In top-level motor racing, the roll cage is substantial, with cross braces behind doors protecting the driver in the event of a side-on shunt. A roll cage can be bolted in, but welding it in place increases the structural rigidity of the car – which also helps improve the car's agility when cornering, providing another key motorsporting edge.

DISCOVERER STT

DID YOU KNOW? *There's a competition out there for all types of vehicles – just ask the British Truck Racing Association!*

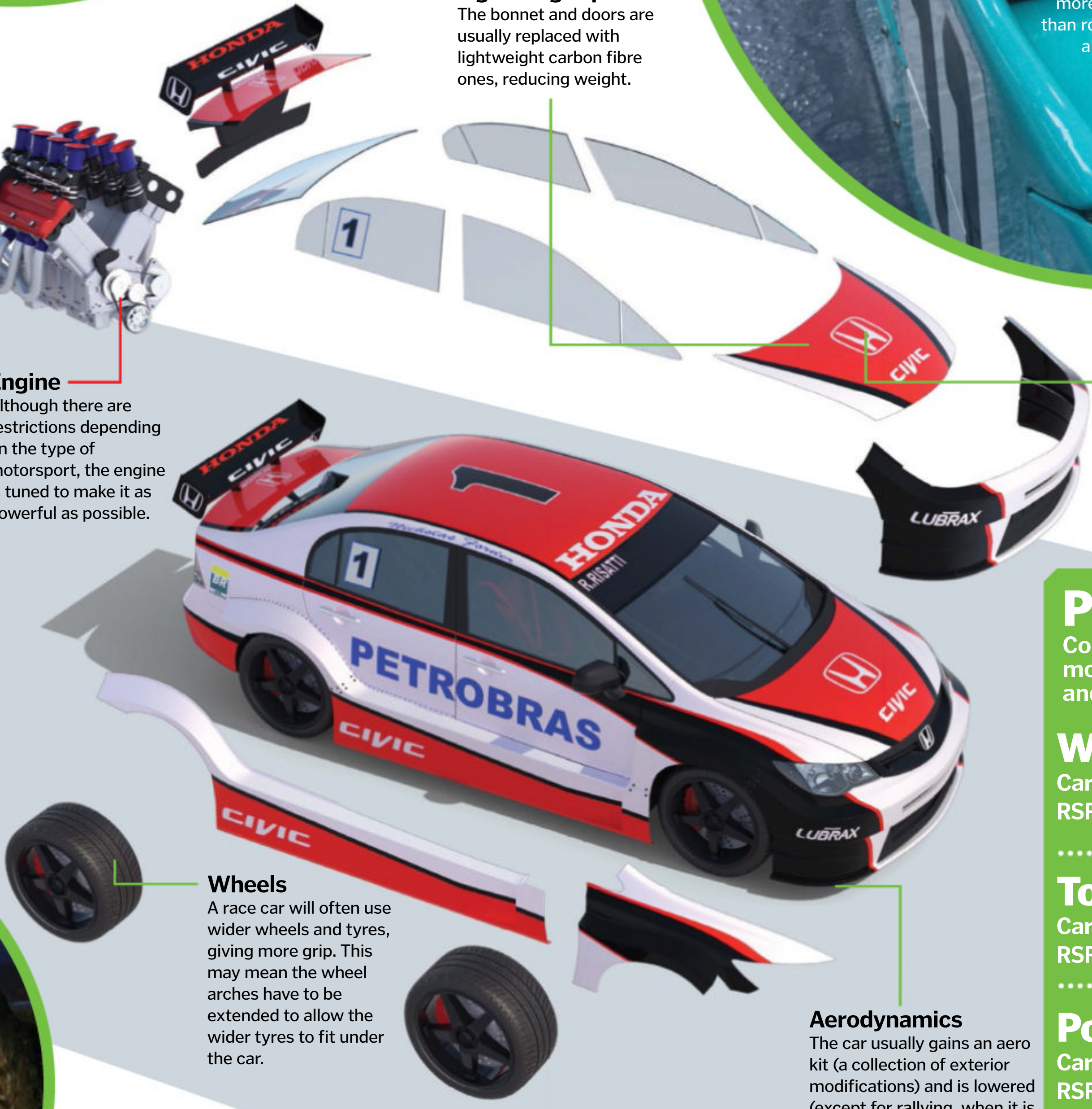
Bucket chair
This keeps the driver rooted to the spot even under high G-forces and protects them in the event of an accident.

Safety belt
A lap belt is replaced by a six-point harness, holding the driver firmly in place.

962
G.FOUCHE
F.KONRAD
W.TAYLOR

Race cars typically feature more vents in their bodywork than road cars because there is a greater need to keep the hardworking engine cool

Lightweight panels
The bonnet and doors are usually replaced with lightweight carbon fibre ones, reducing weight.



Engine
Although there are restrictions depending on the type of motorsport, the engine is tuned to make it as powerful as possible.

Livery
Sponsorship decals are added to the car, which is a core source of income for race teams.

Wheels
A race car will often use wider wheels and tyres, giving more grip. This may mean the wheel arches have to be extended to allow the wider tyres to fit under the car.

Aerodynamics
The car usually gains an aero kit (a collection of exterior modifications) and is lowered (except for rallying, when it is raised), aiding downforce and improving handling.

Rally tyres often feature a deep tread, to provide extra grip even on loose terrain, digging into the floor and increasing traction for the car. Some tyres are embedded with steel studs, offering improved grip in snow and icy conditions for winter rallies.

Porsche 911

Comparing the specs for motorway (911 Carrera) and motorsport (911 RSR)

Weight

Carrera: 1,430kg (3,153lb)
RSR: 1,245kg (2,745lb)

Top speed

Carrera: 295km/h (183mph)
RSR: 306km/h (190mph)

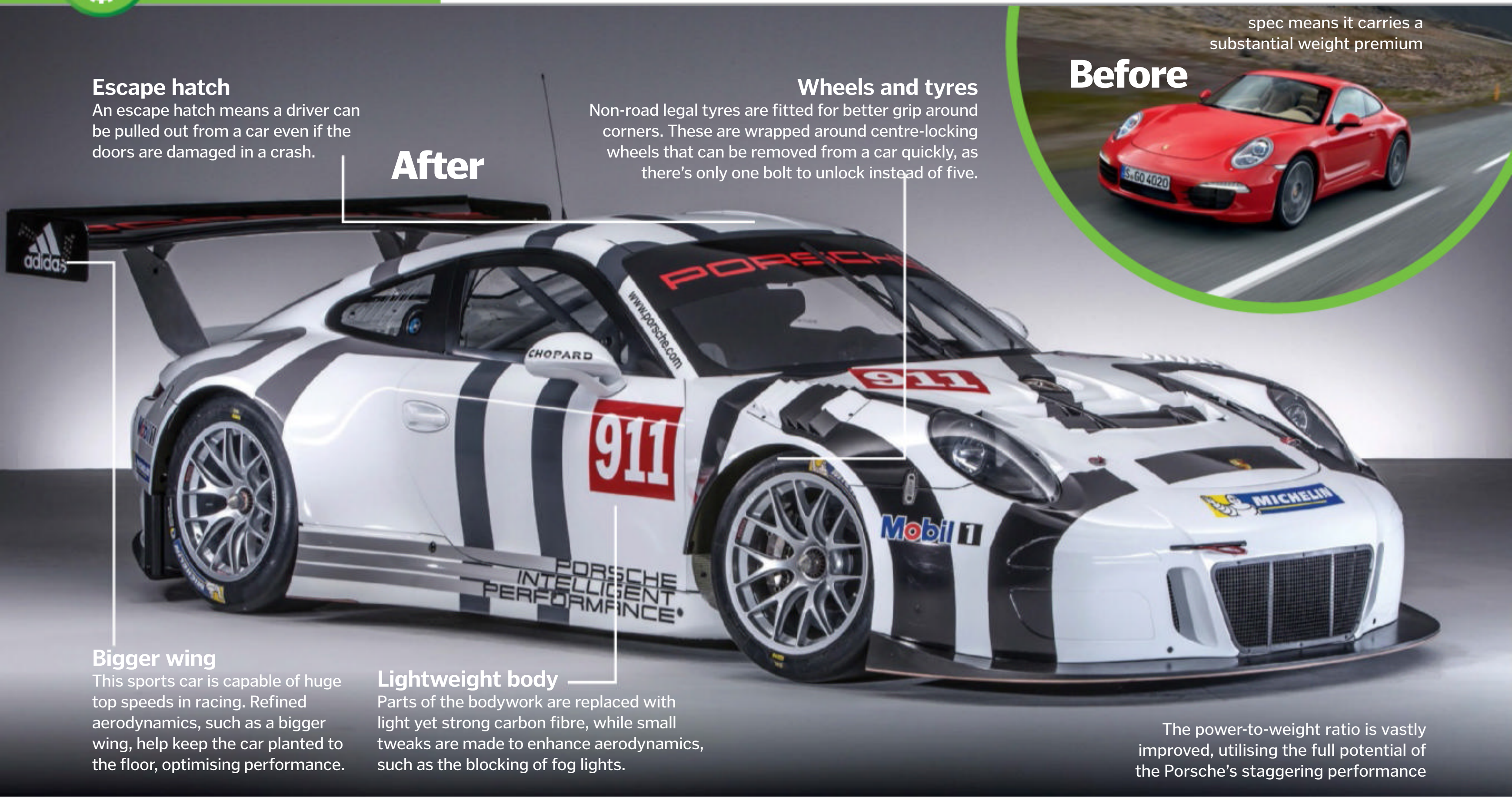
Power

Carrera: 370bhp
RSR: 470bhp

Brake disc size

Carrera: 330mm (13in)
RSR: 380mm (15in)

Illustrations by Nicholas Forder



spec means it carries a substantial weight premium

Before

After

Escape hatch
An escape hatch means a driver can be pulled out from a car even if the doors are damaged in a crash.

Wheels and tyres
Non-road legal tyres are fitted for better grip around corners. These are wrapped around centre-locking wheels that can be removed from a car quickly, as there's only one bolt to unlock instead of five.

Bigger wing
This sports car is capable of huge top speeds in racing. Refined aerodynamics, such as a bigger wing, help keep the car planted to the floor, optimising performance.

Lightweight body
Parts of the bodywork are replaced with light yet strong carbon fibre, while small tweaks are made to enhance aerodynamics, such as the blocking of fog lights.

The power-to-weight ratio is vastly improved, utilising the full potential of the Porsche's staggering performance

Endurance racing

Championing at the ultimate motorsport means going fastest for the longest

While sprint racing has long proved a popular motor-racing discipline, endurance racing is viewed as the ultimate in motorsport circles. With races around a circuit often lasting for up to 24 hours at a time, endurance racing is all about going fast and lasting the distance. To do this, teams take a road car already assured of its performance pedigree (Ferrari currently use their 458 supercar, while Porsche use their ubiquitous 911) and make refinements to guarantee excellence in longevity. The car is then put through its paces in the mammoth race, with the distance shared by a team of drivers.

Vast aerodynamic improvements ensure the car can excel at speeds high above the normal limit for a road, while quick-release wheels and easy-to-replace bumpers are used to cut down on pit stop times. Slick racing tyres are used to provide stellar grip (these are not legal on the road as their zero tread depth makes them a hazard in wet conditions) and bigger brakes are fitted that can tolerate prolonged use in extreme temperatures. Although a bigger fuel tank may appear useful for a long distance race, this is often not needed as carrying lots of fuel can incur a needless weight penalty.

DASHBOARD

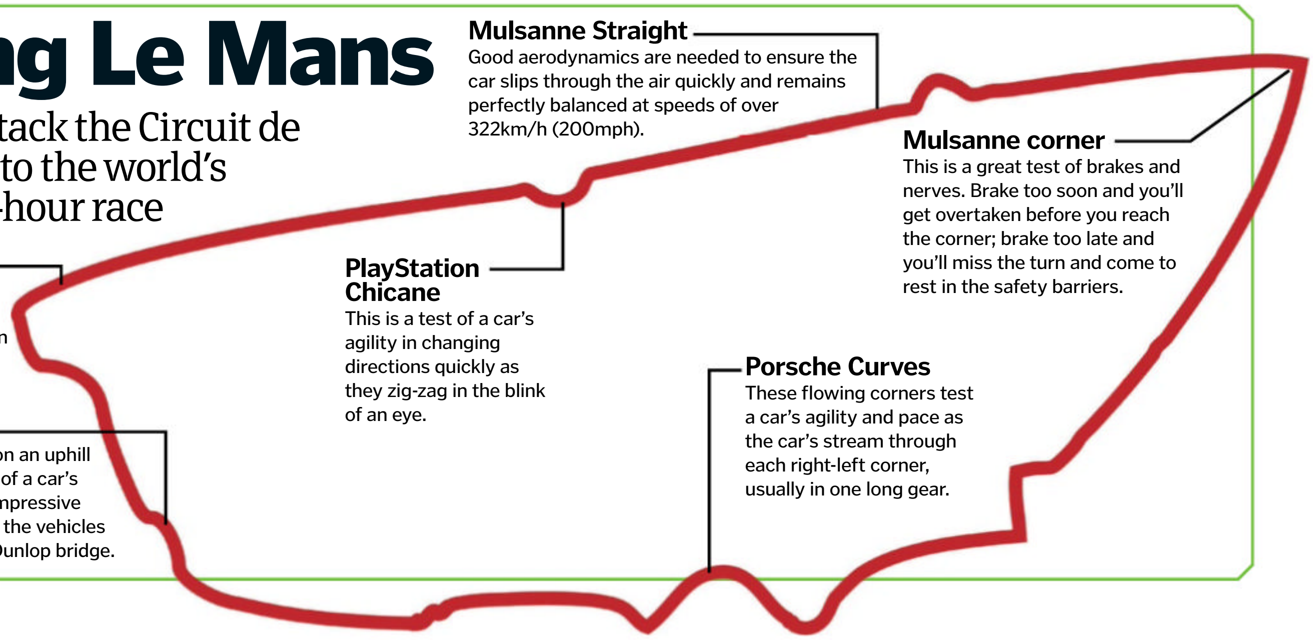
AIR LINE

BUCKET SEAT

ROLL CAGE

Tackling Le Mans

Here's how to attack the Circuit de la Sarthe, home to the world's most famous 24-hour race



Mulsanne Straight
Good aerodynamics are needed to ensure the car slips through the air quickly and remains perfectly balanced at speeds of over 322km/h (200mph).

Mulsanne corner
This is a great test of brakes and nerves. Brake too soon and you'll get overtaken before you reach the corner; brake too late and you'll miss the turn and come to rest in the safety barriers.

Tertre Rouge
It's all about the exit of this corner, as cars will want to put as much power as possible down early to take advantage of the long Mulsanne Straight.

PlayStation Chicane
This is a test of a car's agility in changing directions quickly as they zig-zag in the blink of an eye.

Porsche Curves
These flowing corners test a car's agility and pace as the car's stream through each right-left corner, usually in one long gear.

Dunlop Curve
These series of corners on an uphill gradient are a great test of a car's chassis and provide an impressive display for spectators as the vehicles pass under the famous Dunlop bridge.

Stock car racing

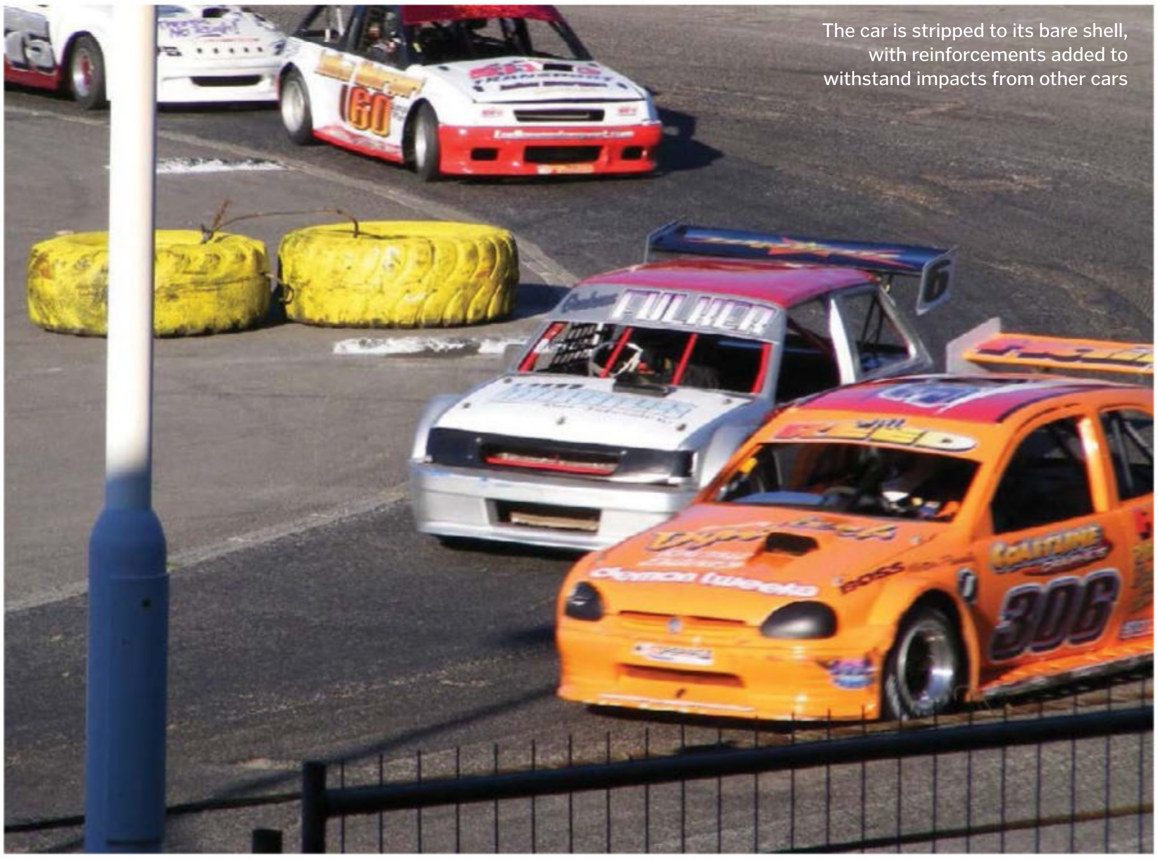
This grassroots discipline involves plenty of contact

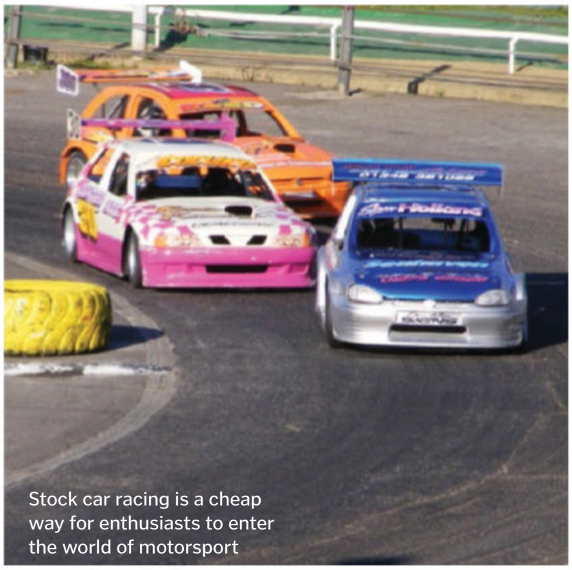
Stock car racing is a cheap, entry-level form of motorsport, worlds away from the lavishness of endurance racing. The idea is to complete as many laps as possible around an oval circuit. However, where contact in other motor sports is frowned upon, here it is perfectly acceptable. This means that the majority of cars competing are low value vehicles saved from the scrap heap.

Due to the contact nature of the sport, stock cars remove all glass windows and lights to stop them shattering on impact. A roll cage is vital here in protecting the driver too, while external bull bars are usually found mounted over the front grill, protecting the engine in the event of an impact to the front of the car, and allowing the vehicle to continue in the race. Cars usually drive clockwise around a circuit, so a left-hand-drive car is desirable as the driver will be placed on the outside of a corner, which will help with natural weight transfer.

A racing steering wheel is fitted (without an airbag of course, as it would go off too easily), while removing the airbox de-restricts airflow into the engine, freeing up more power for the driver. Stock cars are devoid of any fancy liveries or artwork to the body, as it'll only get scraped off or crumpled.

A low-budget hatchback is saved from the scrap heap and prepared for some rough racing


The car is stripped to its bare shell, with reinforcements added to withstand impacts from other cars


Stock car racing is a cheap way for enthusiasts to enter the world of motorsport

Due to the contact nature of the sport, structural enhancements are a key feature of stock car racing

What makes F1 different?

Even to the novice, it's immediately evident that the spectacle of a Formula One car with its open cockpit, huge wing and exposed wheels reveals a vehicle that bears no resemblance whatsoever to any form of road-going contemporary. Whereas most other motorsports mould the competencies of a production car for competition, with Formula One, it's the other way around: new technologies garnered here are then passed on to future production cars. A great example of this is paddle shift gear change, which enables lightning quick gear changes without the driver having to remove their hand from the steering wheel. First pioneered by F1 cars, the technology is now commonplace on every Ferrari leaving the Maranello factory. A more recent evolution is a kinetic energy recovery system, or KERS, which harvests energy from braking and stores this for later use under acceleration. This technology is currently utilised on the McLaren P1 hypercar.

F1 cars are purposely designed from the ground up, unlike the cars used in sports such as rallying or endurance racing

© jph066

Underground engineering

Find out how New York City's subway was constructed more than 100 years ago

Underneath the city's pop-up-book skyline, lies a sprawling subway system. Transporting nearly two billion passengers annually, it operates 365 days a year, 24/7, on over 1,287 kilometres (800 miles) of track, connecting all the boroughs of New York, except Staten Island.

During the late 19th century, New York experienced a population boom due to the huge numbers of immigrants that arrived from Europe, meaning that almost 3.5 million people were living there by 1900. This placed enormous strain on the existing transport systems; roads were more congested and travel became increasingly difficult and dangerous. The authorities realised they needed a subway that could quickly and efficiently move people in, out and around Manhattan.

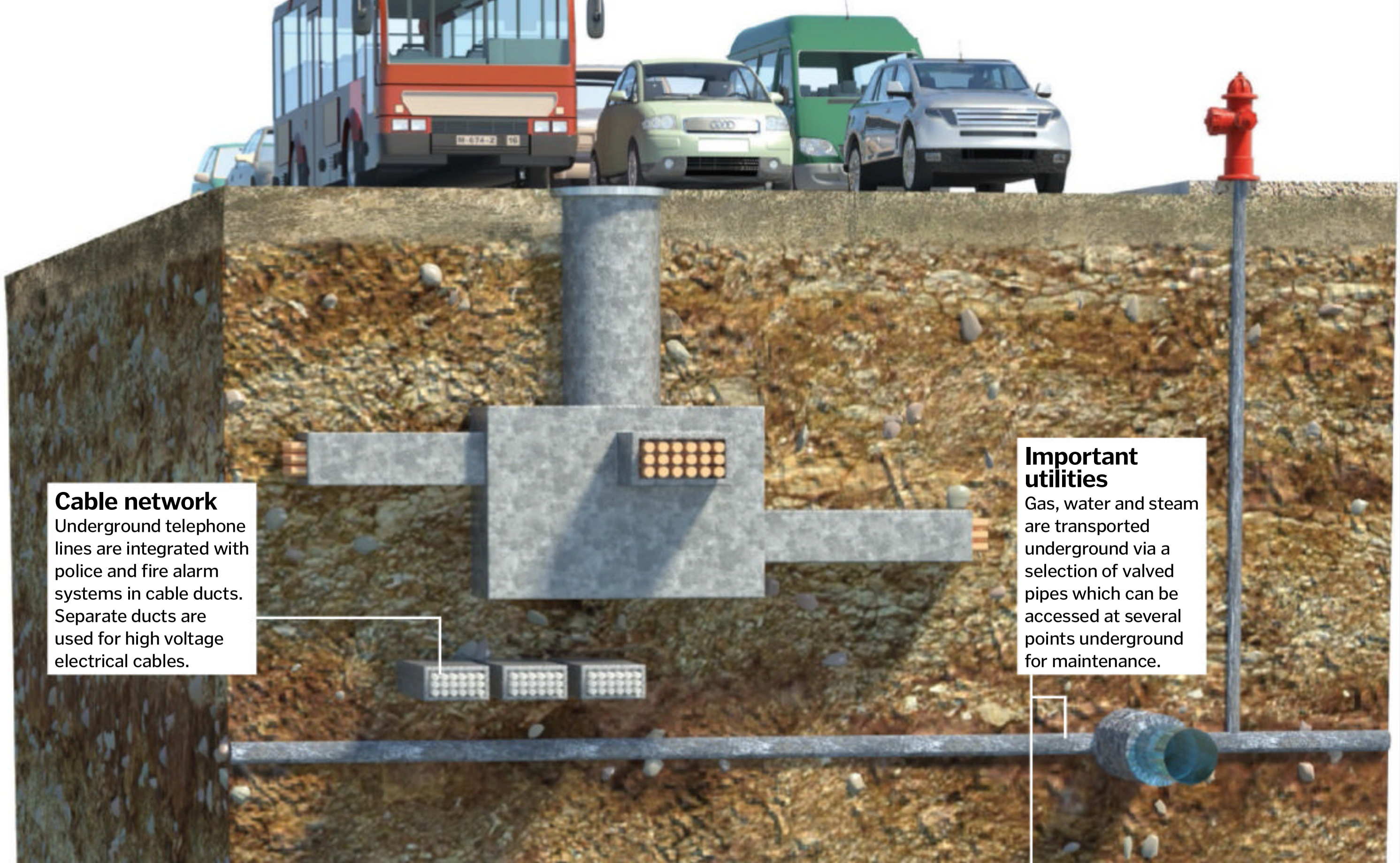
The construction of the first subway line began in 1900. Engineers of the time had to take into account various challenges such as uneven topography, hard bedrock and the sheer number of water, sewage and gas pipes that already lay underground. The project was no mean feat – around 8,000 labourers were employed to excavate the subways, thousands of which sustained injuries and more than 40 lost their lives.

For shallower tunnels, the engineers often preferred to dig down from the road surface, as this made it easier to avoid the utilities that were already buried below. They could then replace the pipes above the subway, modifying their design if necessary, and reconstruct the road surface.

For deeper tunnels, engineers used powerful explosives that were more efficient than digging by hand, but did result in a number of casualties. A variety of techniques were used to overcome some of the installation problems, such as passing the tunnel through a river. To build some of the underwater subway areas, engineers cleverly constructed the tunnel sections above ground and then sunk them into a dredged part of the river, before pumping the water out.

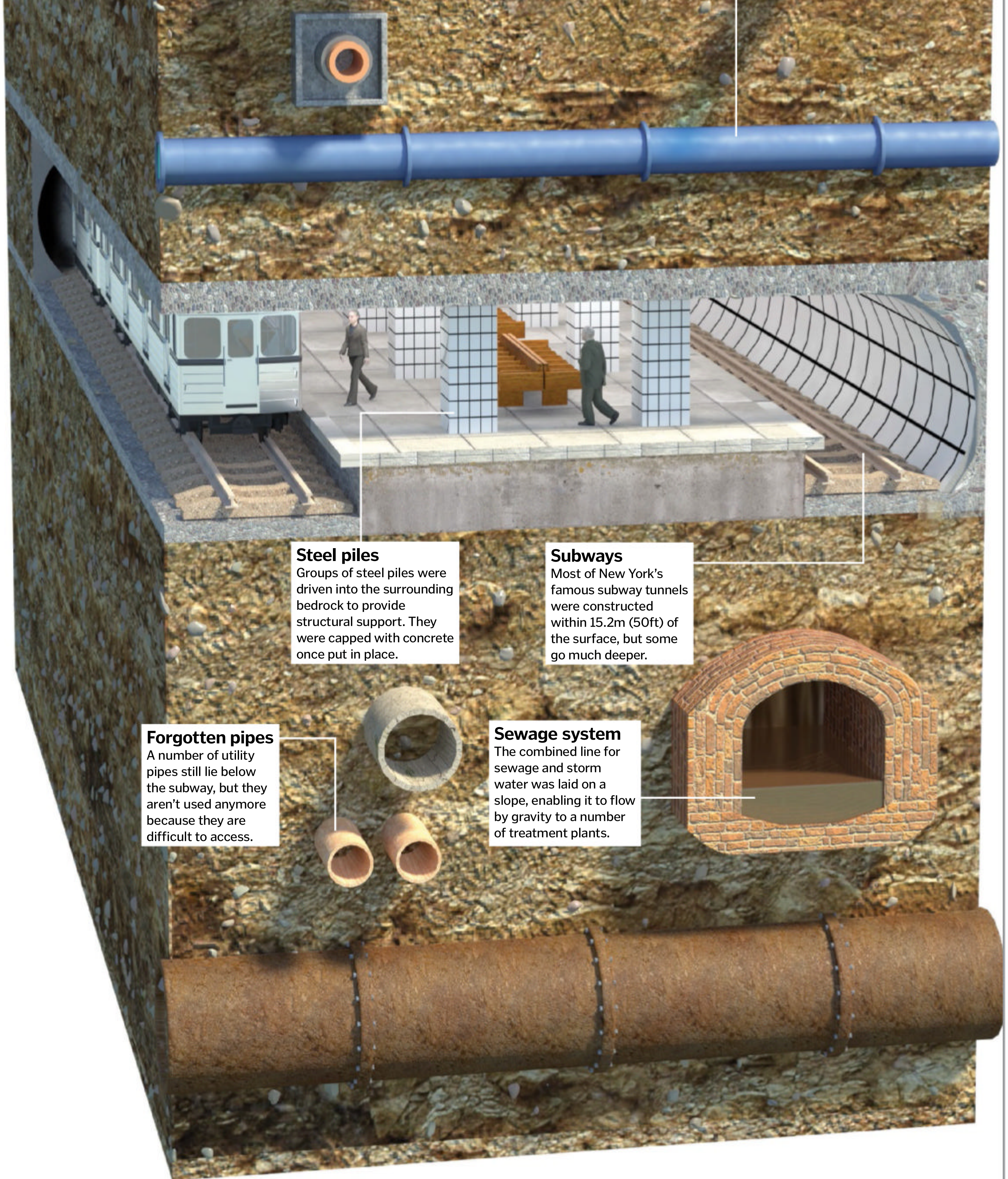
The construction of Second Avenue's subway, which began in 2007

See the distinct layers that make up NYC's vast subterranean network



Cable network
Underground telephone lines are integrated with police and fire alarm systems in cable ducts. Separate ducts are used for high voltage electrical cables.

Important utilities
Gas, water and steam are transported underground via a selection of valved pipes which can be accessed at several points underground for maintenance.



Steel piles
Groups of steel piles were driven into the surrounding bedrock to provide structural support. They were capped with concrete once put in place.

Subways
Most of New York's famous subway tunnels were constructed within 15.2m (50ft) of the surface, but some go much deeper.

Forgotten pipes
A number of utility pipes still lie below the subway, but they aren't used anymore because they are difficult to access.

Sewage system
The combined line for sewage and storm water was laid on a slope, enabling it to flow by gravity to a number of treatment plants.

Expanding the subway system

The New York City underground system is now over 100 years old. It wasn't designed to accommodate the enormous numbers of people that use it daily, so the decision was made to expand it. The plan is to add around 34 kilometres (21 miles) of new tunnel throughout the city, via the East Side Access, Second Avenue Subway, and the 7 Line Extension projects, which are estimated to cost over £9.6 billion ($15 billion).

Engineers would normally use a single tunnel boring machine (TBM) to create the new tunnels. However, in the case of the East Side Access project, such a large tunnel would collapse under the weight of the city above it. This problem has led the designers to employ a slightly unusual technique. Using four smaller TBMs, they will produce four more stable tunnels, which will then be fused to form one larger tunnel. This is accomplished using dynamite to blow out the rock between the small tunnels. Firstly, the top two small tunnels are fused, at which point the roof of the tunnel is reinforced to stop the underground network above collapsing downwards. Once the roof has been strengthened, the remaining two tunnels are joined to create a single tunnel. Work is scheduled for completion in 2022.

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Household plumbing

Find out how a complex system of pipes takes water in and out of your home

When you turn on the tap, you expect a steady stream of water to come flowing out, but have you ever considered how it got there? Its journey begins as rain falling from the sky, which is collected in lakes, rivers, and the ground and then passed through a water treatment plant for cleaning. From there it travels to your home, passing through a meter that records how much water you use, before reaching a clever plumbing system of supply pipes that takes it to where it is needed.

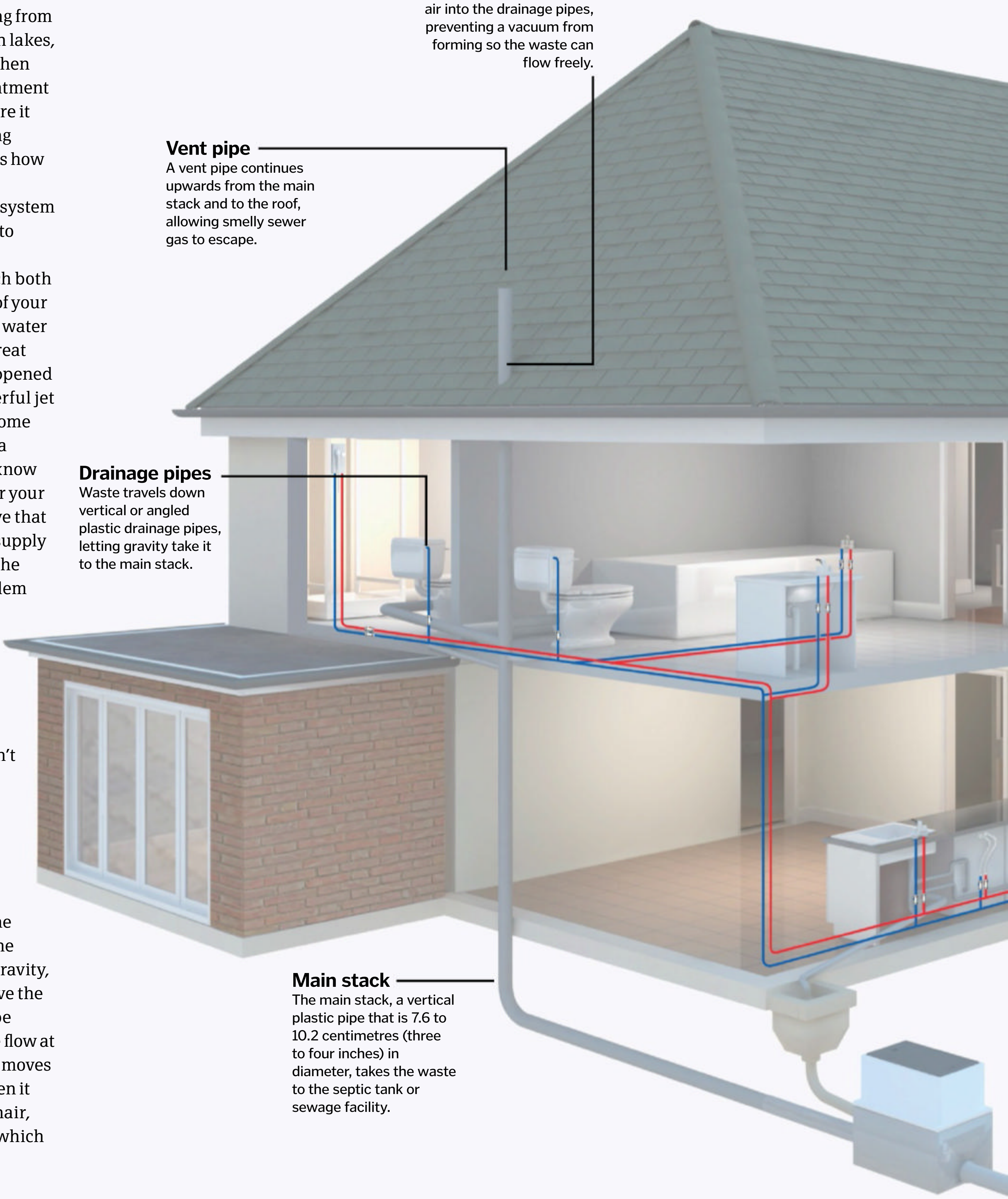
As it has to be able to reach both the upper and lower floors of your house, pressure pushes the water through these pipes with great force. This means if one happened to burst, the resulting powerful jet of water would flood your home very quickly. To avoid such a disaster, it's a good idea to know where the shut-off valves for your property are. The main valve that shuts off your entire water supply is typically located near to the water meter, but if the problem is confined to a particular area, then most sinks, toilets, baths and showers have their own valves for cutting off their individual water supplies.

The water's journey doesn't stop at your taps though, as the waste water you do not need has to travel back out of your property. This is why every house has a drainage system that is completely separate from the supply system that brings the water in. This system uses gravity, rather than pressure, to move the water, so the pipes have to be angled correctly to keep the flow at the right speed. If the water moves too slowly or too quickly, then it could leave debris, such as hair, dirt or toilet paper behind, which will block the pipes.

© Thinkstock; DK Images

From pipe to tap to drain

Water's journey through your home is powered by pressure and gravity



Pressure control
The vent pipe also enables air into the drainage pipes, preventing a vacuum from forming so the waste can flow freely.

Vent pipe
A vent pipe continues upwards from the main stack and to the roof, allowing smelly sewer gas to escape.

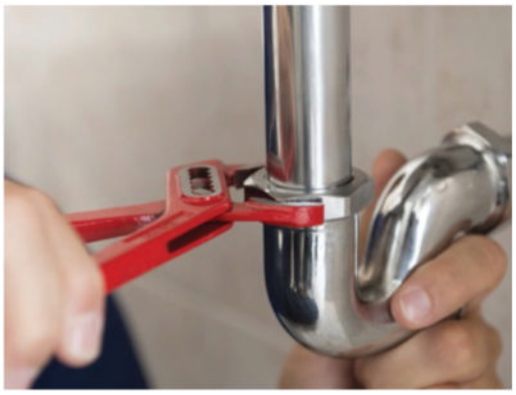
Drainage pipes
Waste travels down vertical or angled plastic drainage pipes, letting gravity take it to the main stack.

Main stack
The main stack, a vertical plastic pipe that is 7.6 to 10.2 centimetres (three to four inches) in diameter, takes the waste to the septic tank or sewage facility.

DID YOU KNOW? *Water-filled traps stop smelly gases escaping from your drains, but rats can still swim up through the pipes*

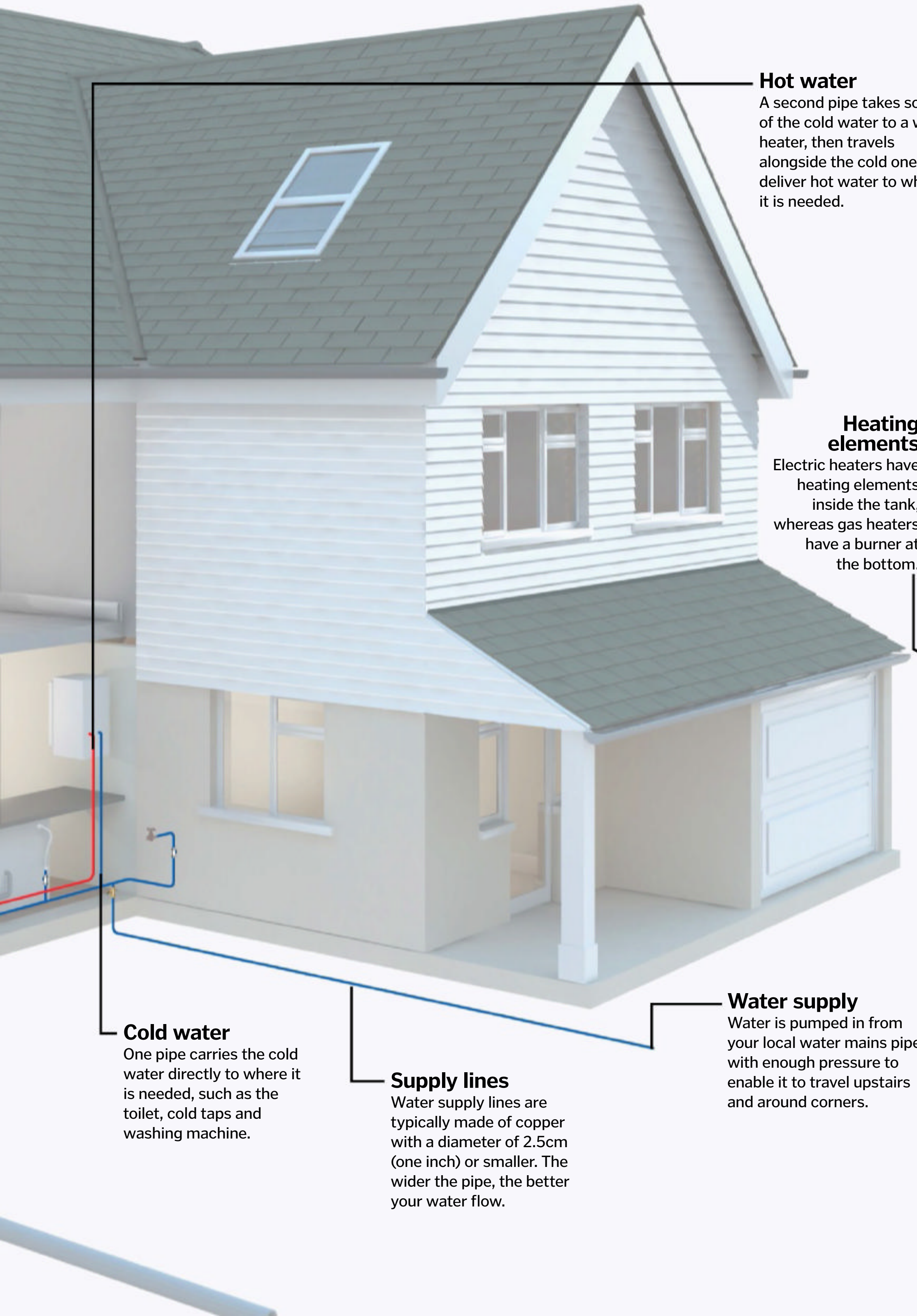
Smell traps

If look under your kitchen sink, you may notice a U-shaped bend in the pipe beneath the drain. This is called a trap and it is found in the drainage pipes of most household fixtures and appliances. The trap plays the vital role of stopping anything from travelling up the pipe and into your house. When the water drains from your sink, there is enough force to push it around the bend of the trap and through the drainage pipe. However, some of the water will stay behind, filling up the trap to form a seal. This stops any sewer gas from escaping through your drain, not only preventing a nasty smell from filling your home, but also stopping harmful bacteria from being carried into the air. These traps can be removed to allow any blockages to be cleared, but some feature a clean-out plug on the bend that can be removed instead.



Ventilation system

The typical drainage system used in most houses is DWV, which stands for the drain-waste-vent system. The vent component is essential for allowing the waste to drain away, as without a vent line that lets air enter through the roof, a vacuum would form in the drainage system. This would have a similar effect to placing your finger over the top of a straw before lifting it out of your drink. Until you remove your finger, the vacuum created holds the liquid in the straw, just as a vacuum in a drainage system would hold the water within the pipe.



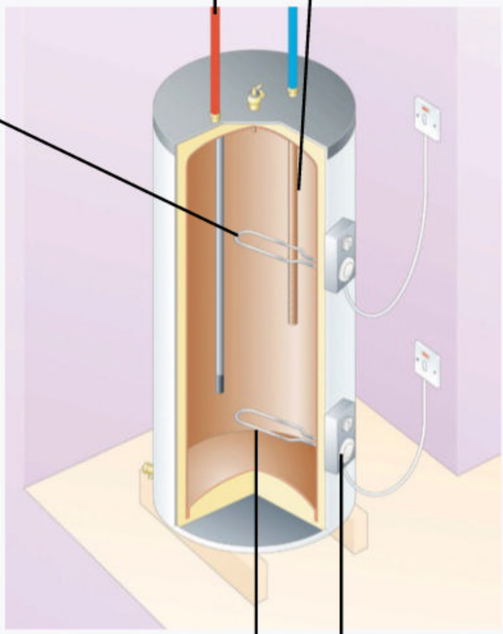
Hot water
A second pipe takes some of the cold water to a water heater, then travels alongside the cold one to deliver hot water to where it is needed.

Cold water
One pipe carries the cold water directly to where it is needed, such as the toilet, cold taps and washing machine.

Supply lines
Water supply lines are typically made of copper with a diameter of 2.5cm (one inch) or smaller. The wider the pipe, the better your water flow.

Water supply
Water is pumped in from your local water mains pipe with enough pressure to enable it to travel upstairs and around corners.

Inside a water heater



Heating elements
Electric heaters have heating elements inside the tank, whereas gas heaters have a burner at the bottom.

Hot water pipe
As the heated water rises above the denser, cold water, it reaches the pipe that carries it away.

Dip tube
Cold water is fed directly to the bottom of the tank from the supply pipe.

Anode rod
A replaceable magnesium or aluminium rod with a steel core protects the tank from corrosion.

Thermostat
This controls the temperature of the water so that it's not too hot or too cold.

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The future of commuting

Explore the cutting-edge technology set to change the way we travel

How long do you spend commuting every day? The average journey time is a soul-sucking 60 minutes, which amounts to over a year of our lives travelling to and from work. Whether it's via road, train or even sky, the commuter experience is blighted by traffic and human or technological errors, leading to delays and expensive fares to supplement archaic modes of transport.

However, the daily slog could be about to change for the better. Thanks to a raft of new technology, we'll see vast improvements to the speed and safety of a commute over the next 50 to 100 years, through improving current transit systems and implementing entirely new modes of transport in the future. These range from faster, more efficient bus services, to sophisticated capsule-based transport that will turn a three-hour journey into a thirty-minute intercity blast.

The future of commuting will also benefit the environment thanks to the development of cleaner, greener vehicles. Electric and hybrid engines are an increasingly popular choice in passenger cars, and the technology is transcending into other forms of transport including motorbikes, buses and even helicopters. This means we'll be producing fewer emissions on our journey to work and we won't be relying on the Earth's diminishing supply of oil to power our various forms of transport. In fact, some forms of transport are likely to produce more energy than they actually use!

Of course, electricity isn't the only source powering commuter vehicles both now and in the future. Innovative forms of travel include linear electric motors for Elon Musk's Hyperloop and maglev technology for Israel's skyTran. We also can't forget the 'number two' Bio-Bus in the UK that's currently transporting passengers between the cities of Bath and Bristol, thanks to the biomethane gas produced from human waste!

No matter what way you look at it, the international workforce of the future has little to fear. They'll be able to relax, sipping coffee as their autonomous car does all the steering, or reclining in a levitating pod that soars above the city. Over the next few pages, take a glimpse into the exciting future of travel but in the meantime, always remember to mind the gap between the train and platform edge!

New and improved Underground systems

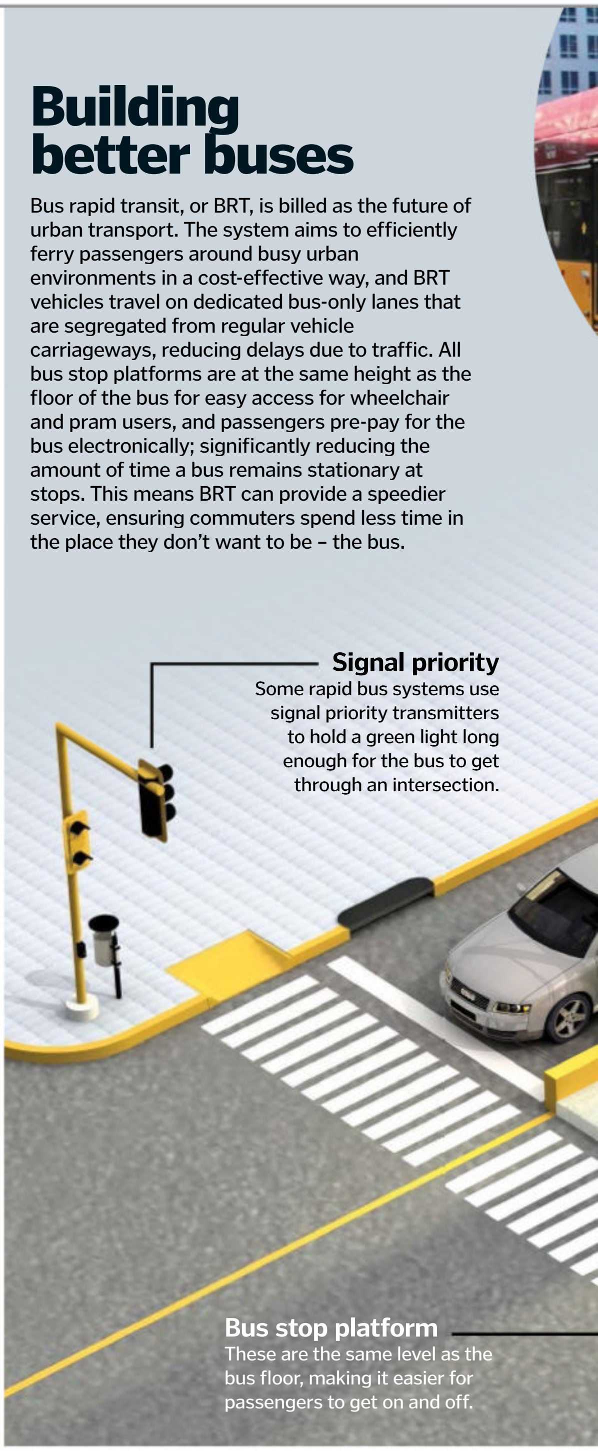
Heathrow
256
PICCADILLY LINE

The London Underground is a vital transport network for Britain's capital city, and Transport for London has plans in place to improve the services and travel experience for its customers. All-new trains are being rolled out on the Piccadilly Line, with the Bakerloo, Central, and Waterloo & City lines following shortly after. The new trains will be air conditioned to make journeys more comfortable, with walk-through carriages to allow for extra room during peak periods of travel. The lines' signalling systems will also be upgraded, helping to eliminate delays. and this September will see the introduction of a 24-hour service for central London stations.

The new train design for London promises to deliver faster, more frequent journeys

Building better buses

Bus rapid transit, or BRT, is billed as the future of urban transport. The system aims to efficiently ferry passengers around busy urban environments in a cost-effective way, and BRT vehicles travel on dedicated bus-only lanes that are segregated from regular vehicle carriageways, reducing delays due to traffic. All bus stop platforms are at the same height as the floor of the bus for easy access for wheelchair and pram users, and passengers pre-pay for the bus electronically; significantly reducing the amount of time a bus remains stationary at stops. This means BRT can provide a speedier service, ensuring commuters spend less time in the place they don't want to be – the bus.

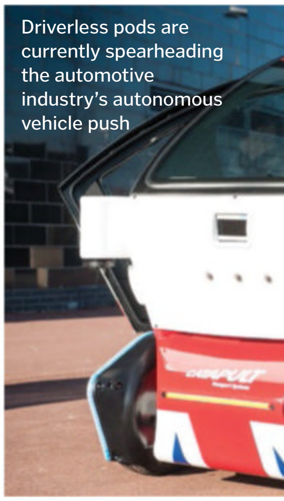


Signal priority
Some rapid bus systems use signal priority transmitters to hold a green light long enough for the bus to get through an intersection.

Bus stop platform
These are the same level as the bus floor, making it easier for passengers to get on and off.

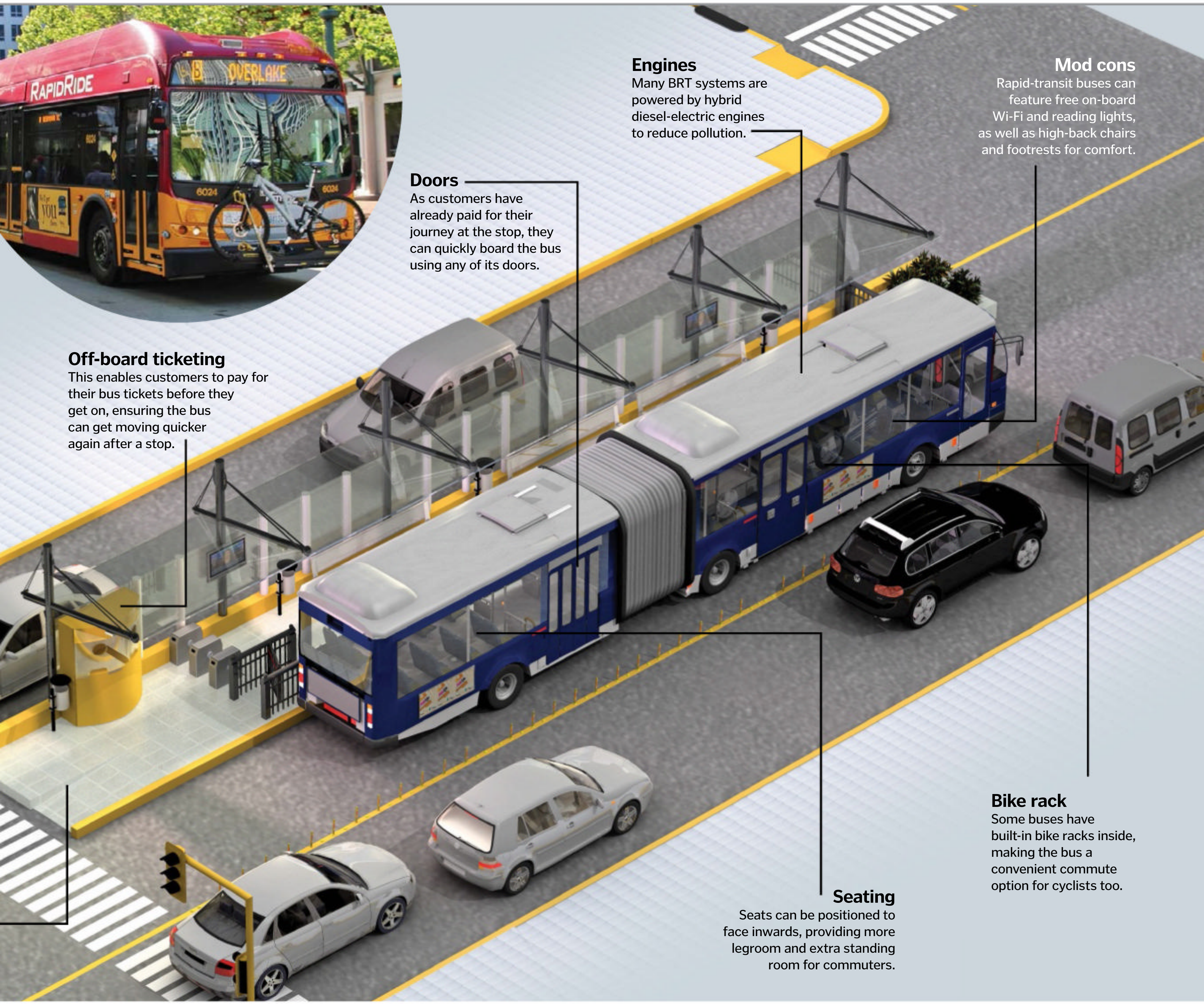
Driverless pods

These small electric vehicles call on the same technology piloted by other driverless car projects, using sensors, lidar and navigation equipment to transport one or two passengers autonomously to their destination via road or pavement. Think this is a technological advancement of the future? Think again. Driverless pods are already being trialled in several UK towns and cities including Oxford and Milton Keynes.



Driverless pods are currently spearheading the automotive industry's autonomous vehicle push

DID YOU KNOW? *Over 1.3 billion journeys were made on the London Underground between 2014 and 2015*



Engines
Many BRT systems are powered by hybrid diesel-electric engines to reduce pollution.

Mod cons
Rapid-transit buses can feature free on-board Wi-Fi and reading lights, as well as high-back chairs and footrests for comfort.

Doors
As customers have already paid for their journey at the stop, they can quickly board the bus using any of its doors.

Off-board ticketing
This enables customers to pay for their bus tickets before they get on, ensuring the bus can get moving quicker again after a stop.

Bike rack
Some buses have built-in bike racks inside, making the bus a convenient commute option for cyclists too.

Seating
Seats can be positioned to face inwards, providing more legroom and extra standing room for commuters.

Zero emission motorbikes

They're an ideal form of transport to zip one or two people at a time through busy city streets, but internal combustion-engine motorcycles are still damaging the environment in the same way cars do. However, with electric car sales on the rise, the same technology is being applied to their two-wheeled counterparts with the introduction of eco-friendly electric motorbikes. Some models can offer an impressive range of up to 300 kilometres (185 miles) per charge, which is ample for cutting through traffic-laden city streets.

© Transport for London; Solgo

The Hyperloop

Elon Musk's fascination with revolutionising the way we travel doesn't just include the electric Tesla road vehicle or SpaceX rockets. The entrepreneur's most innovative idea yet focuses on a high-speed super shuttle called the Hyperloop. This *Futurama*-style tube concept is billed as a high-speed transport system for both people and cargo, capable of whizzing between San Francisco to Los Angeles – a whopping total distance of around 600 kilometres (372 miles) – in just 35 minutes.

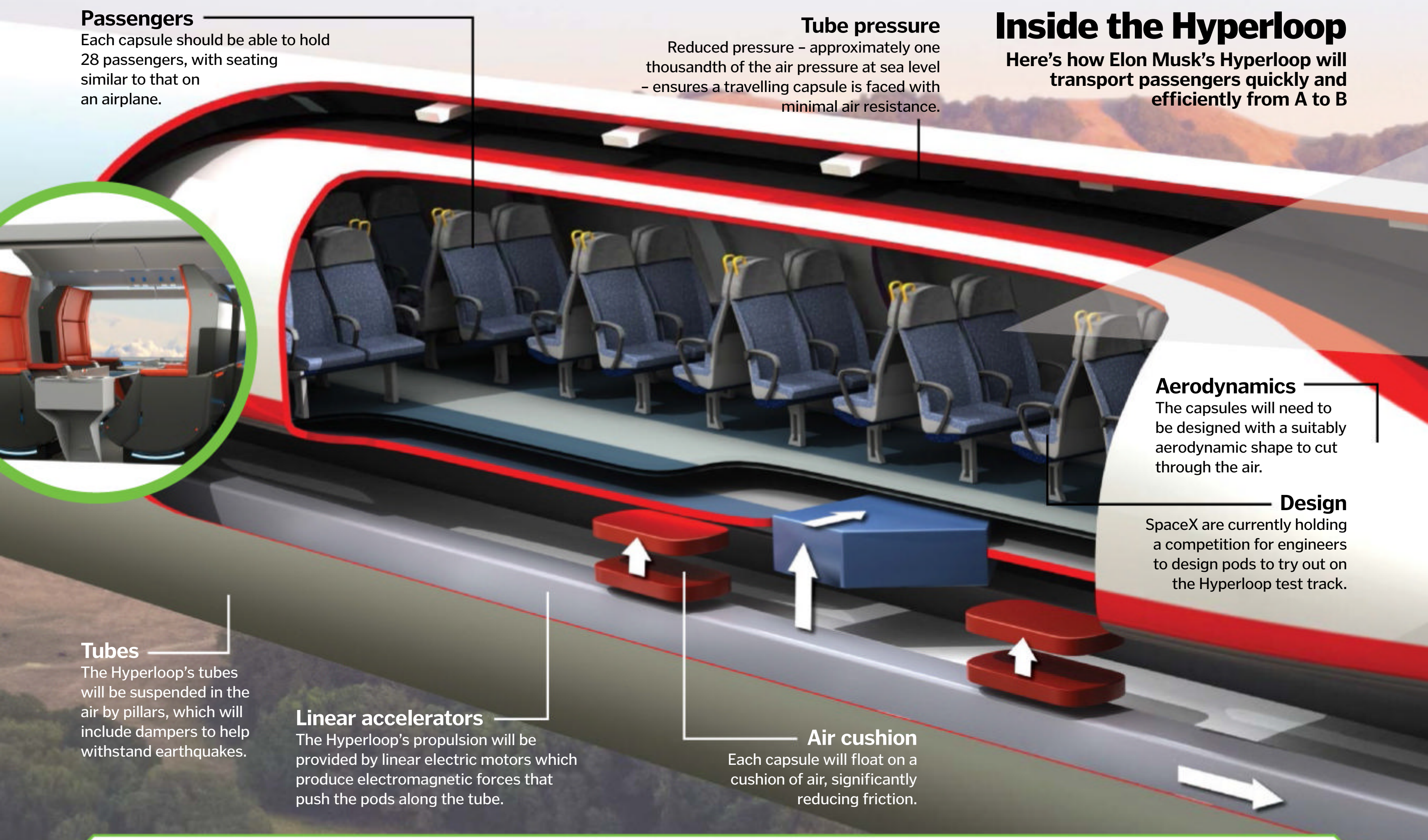
This unconventional design involves pods travelling through a tube at almost the speed of sound. To achieve such an incredibly quick journey between the two Californian cities, the Hyperloop's tubes will be depressurised to significantly reduce atmospheric drag on the pods as they zip through. Musk ruled out using a complete vacuum, however, since this would be difficult to maintain and even so much as a tiny crack in the tube would completely stop the whole system working.

The pods will have aluminium ski-like fixtures that will have high-pressure air pumped through them, allowing the capsules to levitate on a cushion of air, quite similar to an air hockey table. These skis will pass through tracks of linear induction motors positioned all the way throughout the tube which will then electromagnetically accelerate or decelerate the travelling pods as required.

An eight-kilometre (five-mile) test track of the Hyperloop system is due to be built in California next year. If the project is a success, we could soon see a super-quick form of transport for people and goods that doesn't cost lots to run, making Hyperloop is undoubtedly one of the most exciting advancements to ever occur in the travel industry.

Inside the Hyperloop

Here's how Elon Musk's Hyperloop will transport passengers quickly and efficiently from A to B



Passengers
Each capsule should be able to hold 28 passengers, with seating similar to that on an airplane.

Tube pressure
Reduced pressure – approximately one thousandth of the air pressure at sea level – ensures a travelling capsule is faced with minimal air resistance.

Aerodynamics
The capsules will need to be designed with a suitably aerodynamic shape to cut through the air.

Design
SpaceX are currently holding a competition for engineers to design pods to try out on the Hyperloop test track.

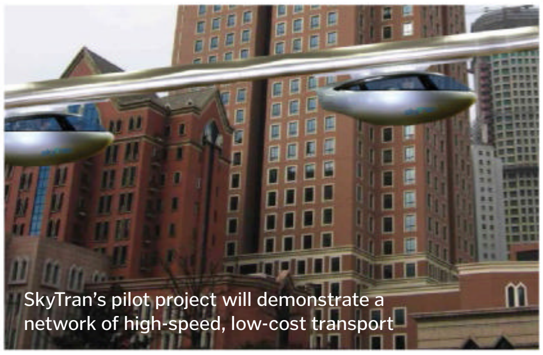
Tubes
The Hyperloop's tubes will be suspended in the air by pillars, which will include dampers to help withstand earthquakes.

Linear accelerators
The Hyperloop's propulsion will be provided by linear electric motors which produce electromagnetic forces that push the pods along the tube.

Air cushion
Each capsule will float on a cushion of air, significantly reducing friction.

A taxi service in the sky

Personal helicopters aren't the only next-gen form of travel whisking passengers away from street level. SkyTran, which has a pilot project currently in development in Israel, is a monorail-like system with pods suspended six to nine metres (20 to 30 feet) above the ground and provides high-speed, low-cost transport for its users. Passengers simply summon a pod to a station via an app on their smartphone and it takes them where they want to go. The system works using maglev technology which utilises magnets in the rail to levitate the two-person pods so they are not in direct contact with the track, reducing friction. The cutting-edge technology, developed with NASA's Ames Research Center, means that the pods generate their own levitation as they move, only requiring an initial burst of power to start and stop. A 500-metre (1,640-foot) test track will be built at the campus of Israel Autospace Industries, where the pods will be able to reach speeds of up to 70 kilometres (43.5 miles) per hour. If the trial is successful, this all-new form of transport will be installed in the heart of Tel Aviv, before being introduced to cities across the world.

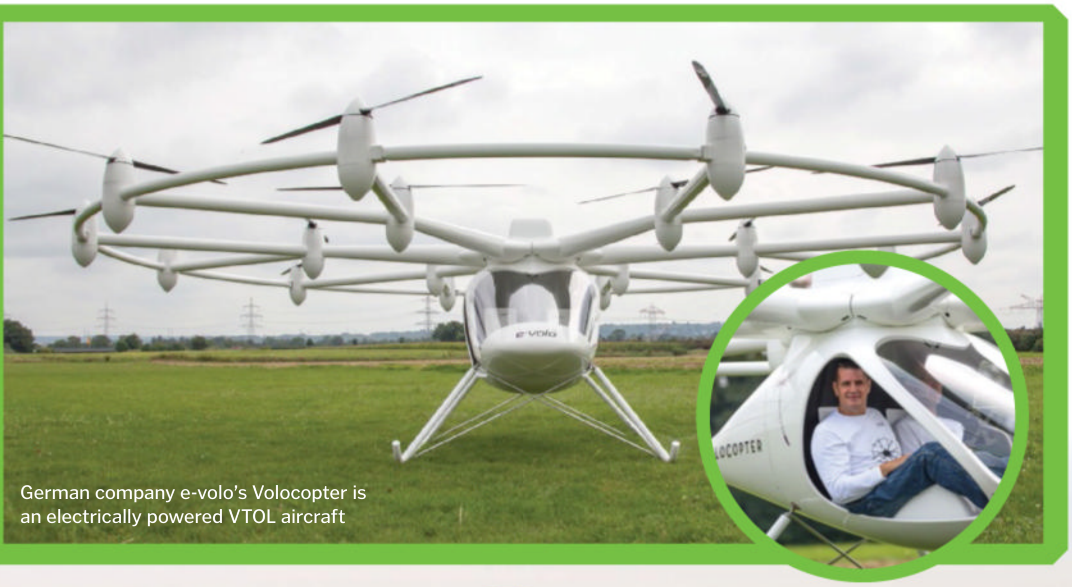


SkyTran's pilot project will demonstrate a network of high-speed, low-cost transport

DID YOU KNOW? *Elon Musk says that his Hyperloop would cost 10% of the $70bn rail being built between LA and San Francisco*

Personal helicopters

Traffic is swelling on roads around the world and in Brazil the wealthy are looking to avoid this altogether – by taking to the skies in personal helicopters. As such, novel designs such as the Volocopter are becoming increasingly popular among the urban elite. Key to the success of vehicles like the manned Volocopter, which can carry up to two passengers at a time, is that they are capable of a vertical take-off or landing, making it very useful in tightly packed cities where space is at a premium. The Volocopter is powered by electric motors, making it quieter and more environmentally friendly than a conventional helicopter. The lack of an internal combustion engine also eliminates the vibrations and the high noise level associated with helicopters, meaning the Volocopter is much more comfortable for its occupants.


e-volo
VOLOCOPTER

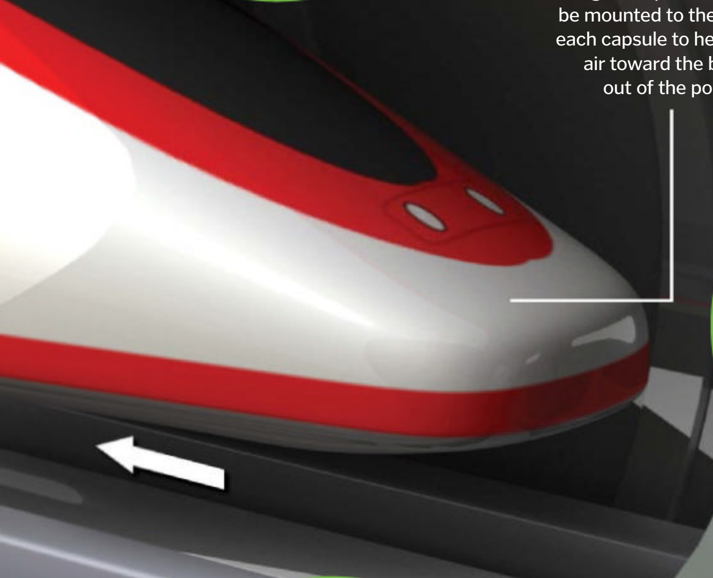
German company e-volo's Volocopter is an electrically powered VTOL aircraft

Solar power

The Hyperloop looks set to harness the Sun's energy by installing solar panels along the roof of the tube.

Speed

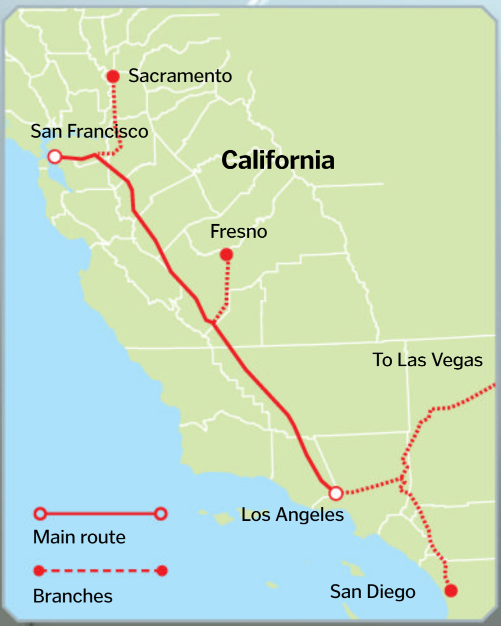
The capsules will whiz through the Hyperloop at a top speed of about 1,223km/h (760mph) – just below the speed of sound.



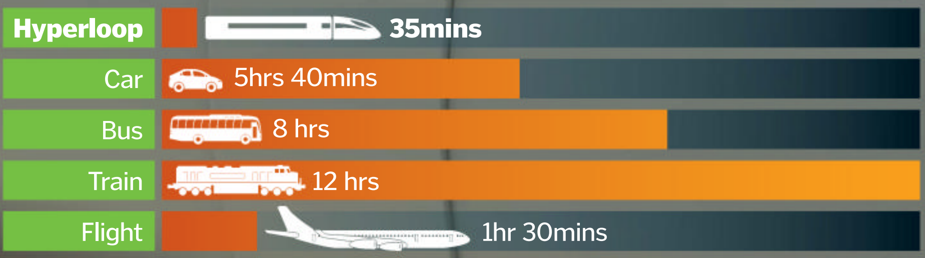
Air compressor

A large compressor fan will be mounted to the front of each capsule to help direct air toward the back and out of the pod's path.

OVERHEAD STORAGE
MOTION SENSOR
SEAT ROTATOR


Sacramento
San Francisco
California
Fresno
To Las Vegas
Los Angeles
San Diego
Main route
Branches

Journey times from LA to San Francisco



© Thinkstock; Argodesign

Driver versus driverless

How the Audi RS7 driverless car can set a faster lap time on its own than with a human at the wheel

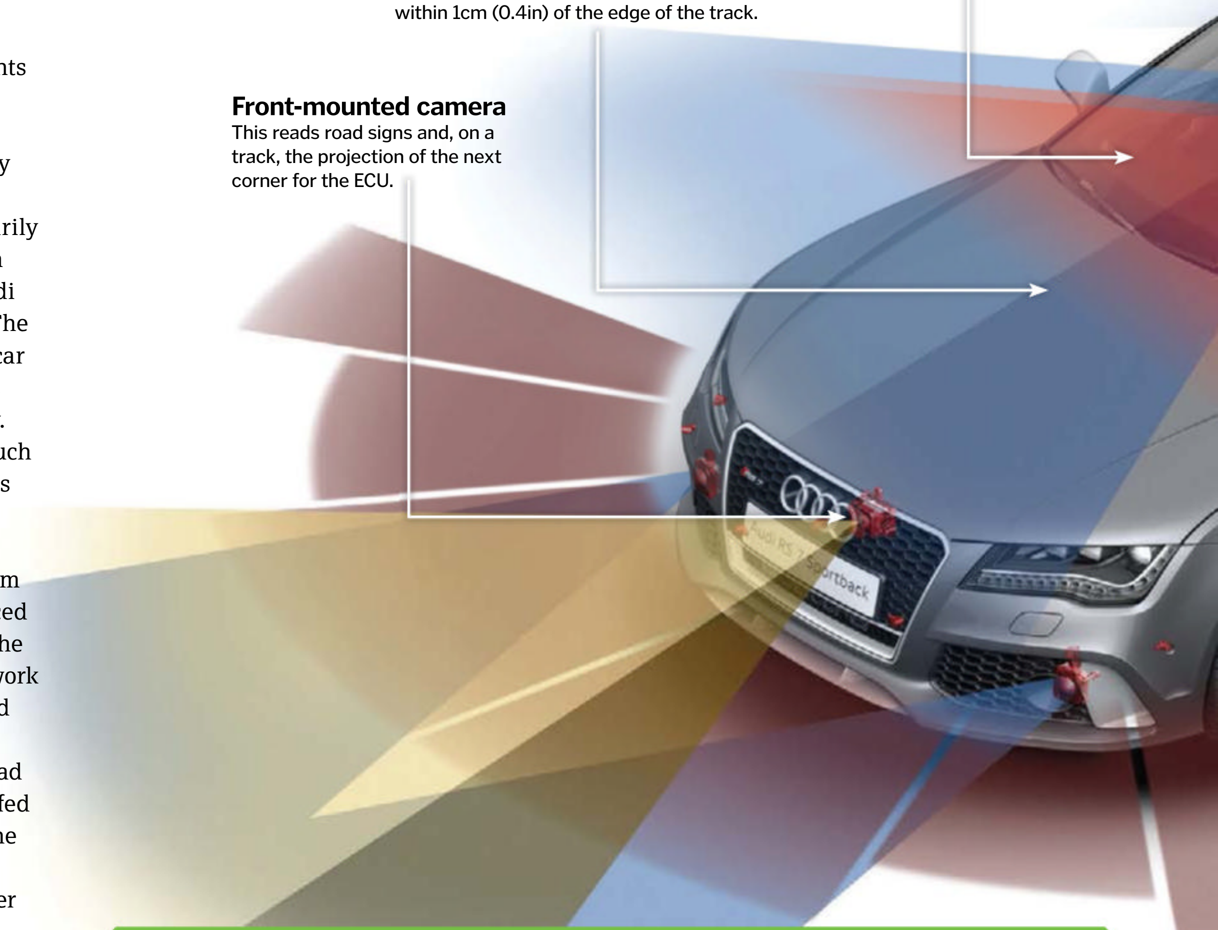
It's the age-old debate: is technology better than the talents of humans? In the automotive world, this argument is fast rearing to a head, with driverless cars now being fully tested on public roads around the world. However, while driverless cars are primarily aiming to be safer than those piloted by a human being, German manufacturer Audi wanted to find out if they are faster, too. The answer to this is the Audi RS7 driverless car prototype, a pumped-up sports car that's been adapted with driverless technology.

The RS7 driverless concept works in much the same way as a conventional driverless car currently being developed by other manufacturers, including Toyota and Google. As well as an advanced GPS system with pinpoint accuracy, cameras are placed around the vehicle that 'read' signs and the layout of the road or track ahead. These work in tandem with sensors and radars dotted around the vehicle, which constantly monitor the proximity of the car to the road and other objects. All this information is fed to a central computer, which processes the info and operates the car accordingly.

Where the Audi RS7 triumphs over other driverless cars, though, is not only in the speediness of this entire process, but also in its intelligence. On a track, a 'racing line' is taken by drivers to get around the track in the quickest time. This involves using the entire width of the track, braking at the last possible moment before a corner, and keeping the car perfectly balanced throughout. As a thrash around the Hockenheim circuit demonstrated, the driverless RS7 prototype was found to take a very precise racing line on the track, nearly identical to that of a seasoned racing driver. The technology isn't without merit, either: a driverless RS7 actually beat a lap time around the Ascari circuit (by two whole seconds!) set by a human being in an identical car.

The driverless Audi RS7 in action

Here's how the driverless Audi RS7 prototype races round a track without any human input



Differential GPS
This improved GPS system is accurate to within 10cm (4in), far better than the 15m (50ft) accuracy of a conventional GPS system.

Mapping programmes
Different mapping programmes are available, but at its limit it can travel at up to 240km/h (149mph) and position itself to within 1cm (0.4in) of the edge of the track.

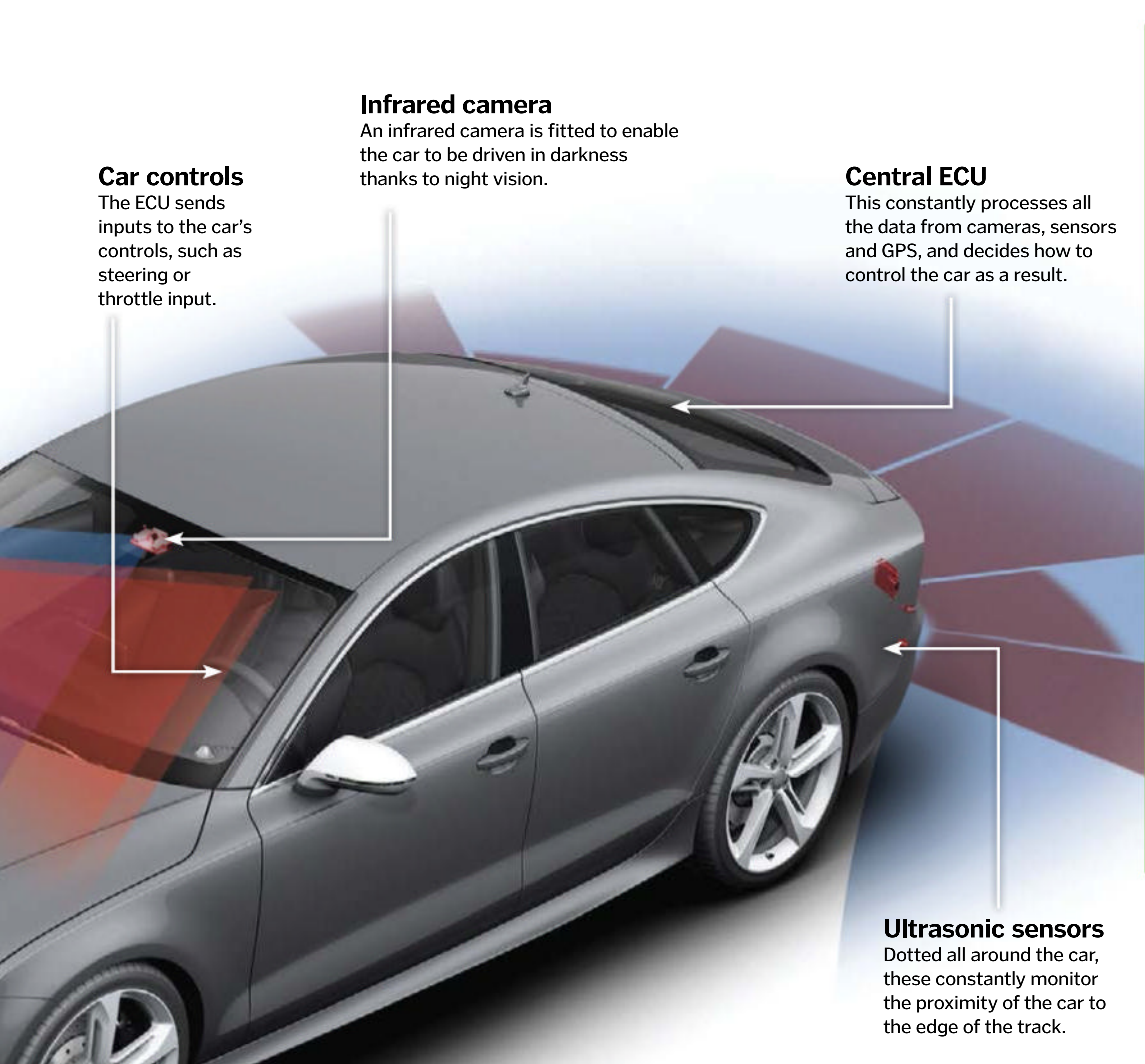
Front-mounted camera
This reads road signs and, on a track, the projection of the next corner for the ECU.

The evolution of the driverless car

The driverless car industry is fast evolving within the automotive industry. Interestingly, it's not car manufacturers themselves that are at the forefront of the technology either: that accolade goes to technology giant Google, which has developed a unique pod-like vehicle that contains a single cushioned bench inside for all occupants to sit on. Materials used on the Google car are also ground-breaking, with a bendy facia and plastic windscreen implemented to help cushion the blow to a human in the unlikely event of a collision.

Other companies such as Toyota or Volvo have been busy adapting their own conventional passenger vehicles to accommodate driverless tech, but the roof-mounted radar and bigger computers have often proved unsightly and impractical. But there's more: rumours are also gathering pace that Apple is developing its own autonomous vehicle, so watch this space...

DID YOU KNOW? *In 2010, a driverless Audi TTS successfully took on the Pikes Peak hillclimb challenge*

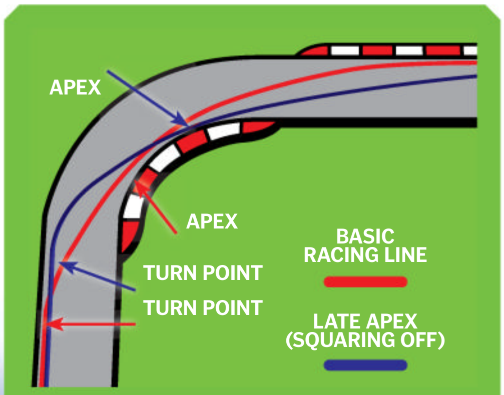


Car controls
The ECU sends inputs to the car's controls, such as steering or throttle input.

Infrared camera
An infrared camera is fitted to enable the car to be driven in darkness thanks to night vision.

Central ECU
This constantly processes all the data from cameras, sensors and GPS, and decides how to control the car as a result.

Ultrasonic sensors
Dotted all around the car, these constantly monitor the proximity of the car to the edge of the track.



Racing line: the quickest way around the track

Race drivers will take a certain line around a race track, in order to complete a lap in the shortest time possible. This is called a 'racing line' and is best described as a route that cuts through corners – without cheating, of course – most effectively, and enables the driver to keep their foot on the accelerator pedal for the longest possible time. Different racing drivers will interpret different racing lines on a track – there is no right or wrong here – though drivers in a world-class competition like Formula One will likely take very similar lines after years of experience and practice on each circuit.

Audi's RS7 driverless concept could be bad news for professional racing drivers in the long term

© Audi; Google/Rex Features

Plugs from around the world

Learn why we are unlikely to see a universal plug any time soon

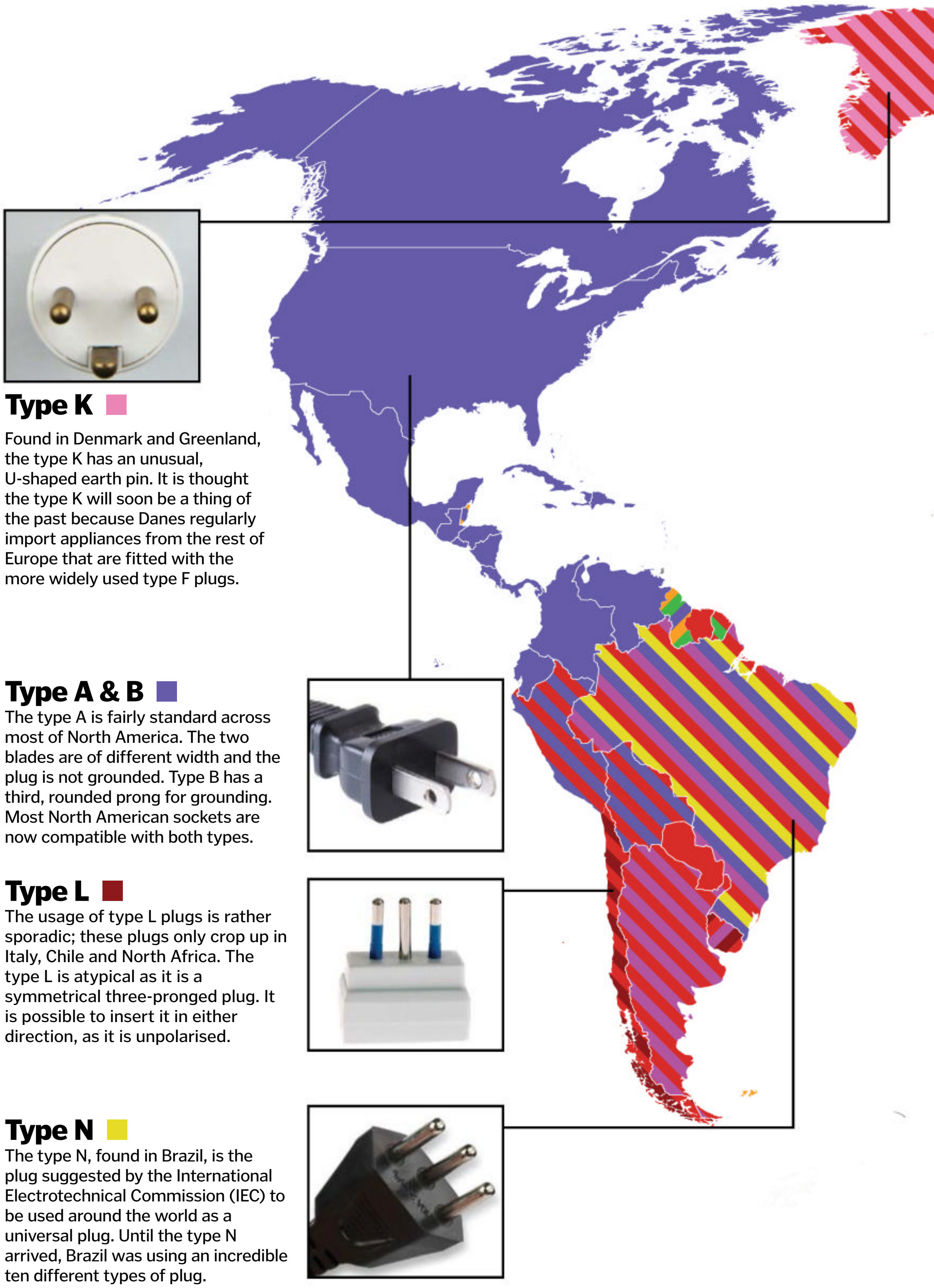
If you ever plan on charging your laptop abroad, be sure to check before you travel – many countries don't have a national standard of electrical outlets so you could find yourself grappling with as many as six different plugs and sockets!

As travelling became affordable to the masses, the problem of using the correct plug for our electrical devices from home started to grow. In an age where technological advancements continue to amaze, it seems bizarre that we cannot introduce a plug we can use globally.

Why so many countries have different plugs is mainly down to the fact they prefer to develop their own standards. Harvey Hubbell designed a "Separable Attachment-Plug", which allowed non-lighting devices to use a light socket for power. This was adapted and refined to create a three-pronged plug which included the addition of a grounding wire to provide protection from electric shocks.

Throughout the early-1900s, inventors around the world were creating their own version of this pioneering plug. During this period, international plug compatibility was not of concern, as electronics hadn't reached many parts of the world. With every country having different historical circumstances, the plug came in at different times where different technologies were available. Even as recently as the 1950s, the UK was developing a plug with no consideration for the rest of the world.

The question on any frequent traveller's lips is, "when will we see a universal plug?" At the moment, the consensus is never. Although it would make sense, the motivation for countries to pay for a universal plug is very low, considering they have all invested heavily in their own systems. Moreover, there would be an inevitable interim period where multiple plug standards would exist within one country, which we know from experience to be dangerous. Even if countries decided to adopt a standard plug system, at least two standards would have to exist – a 110-volt flat plug along with a 240-volt round plug. However, two would be a vast improvement on over a dozen types globetrotters currently have to deal with.



Type K ■

Found in Denmark and Greenland, the type K has an unusual, U-shaped earth pin. It is thought the type K will soon be a thing of the past because Danes regularly import appliances from the rest of Europe that are fitted with the more widely used type F plugs.

Type A & B 🟪

The type A is fairly standard across most of North America. The two blades are of different width and the plug is not grounded. Type B has a third, rounded prong for grounding. Most North American sockets are now compatible with both types.

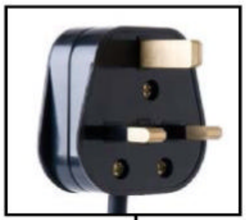
Type L 🟥

The usage of type L plugs is rather sporadic; these plugs only crop up in Italy, Chile and North Africa. The type L is atypical as it is a symmetrical three-pronged plug. It is possible to insert it in either direction, as it is unpolarised.

Type N 🟨

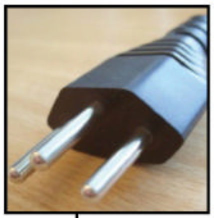
The type N, found in Brazil, is the plug suggested by the International Electrotechnical Commission (IEC) to be used around the world as a universal plug. Until the type N arrived, Brazil was using an incredible ten different types of plug.

DID YOU KNOW? *The copper shortage after WWII forced Britain into designing a new plug, which is still in use today*



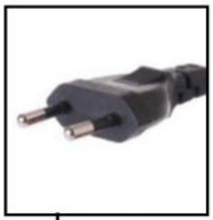
Type G 🟧

Type G plugs are synonymous with the United Kingdom, but are also found in other countries such as Singapore. This has three rectangular prongs. The type G is one of the safest kinds of plug in the world, but has the downside of being bulky.



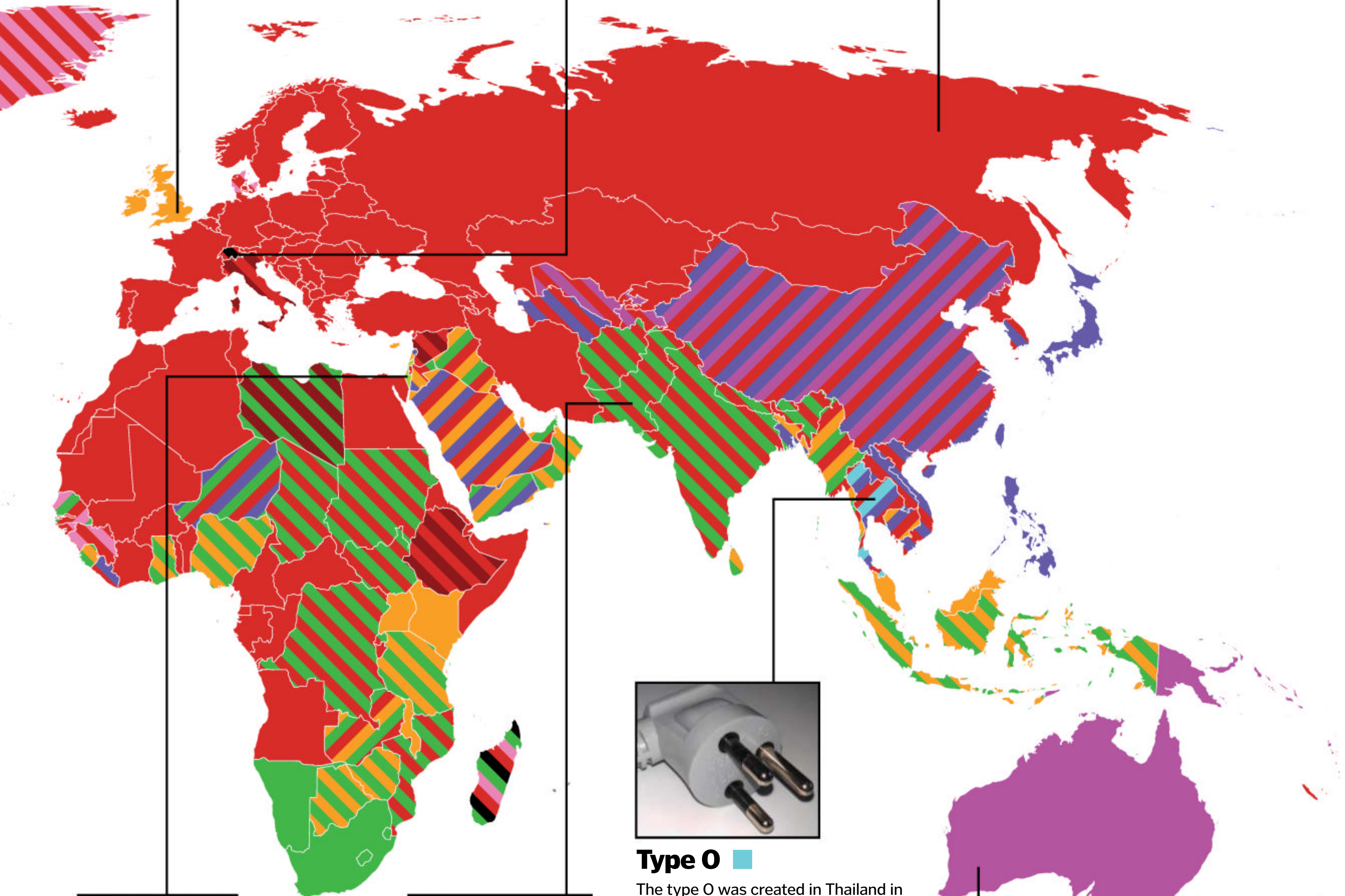
Type J ⬛

This plug type is found in Switzerland and Liechtenstein, although Switzerland has their own standard, the SEC 1011. It's structurally similar to type C, other than its additional grounding pin. A type J socket will accept a type C plug perfectly.



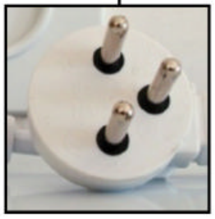
Type C, E and F 🟥

All three of these plugs operate in the 220 to 240-volt range. Type C is credited with being the most widely used international plug. Type E is found in France and Belgium. Type F is found across Europe, and was designed in Germany after WWI.



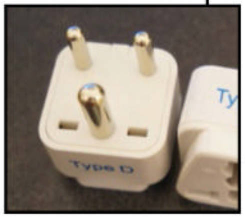
Type O 🟦

The type O was created in Thailand in 2006, and is still being phased in. Why Thailand decided to design and implement a new type of plug when multiple alternatives already exist is a mystery, and highlights the difficulties of adopting a new standard.



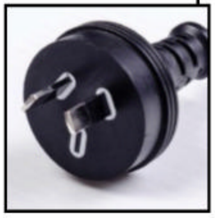
Type H 🟩

The type H is unusual as it is used solely in Israel. Originally, it was three flat prongs in a V-shape, but since 1989 this design has been phased out in favour of three circular pins. The Type H socket will also accept type C plugs.



Type D & M 🟩

The type D is mainly used in India but is compatible with type C sockets. This plug was the standard in Great Britain before 1947. Type M is found in South Africa and is a three-pin, grounded plug. It requires 220 to 240 volts and looks like a type D with larger pins.



Type I 🟪

The type I is found in Australia and New Zealand, and is available in a two or three-pronged option. This type was favoured over the UK's type G because Australian manufacturers could produce flat pins more easily than round ones.

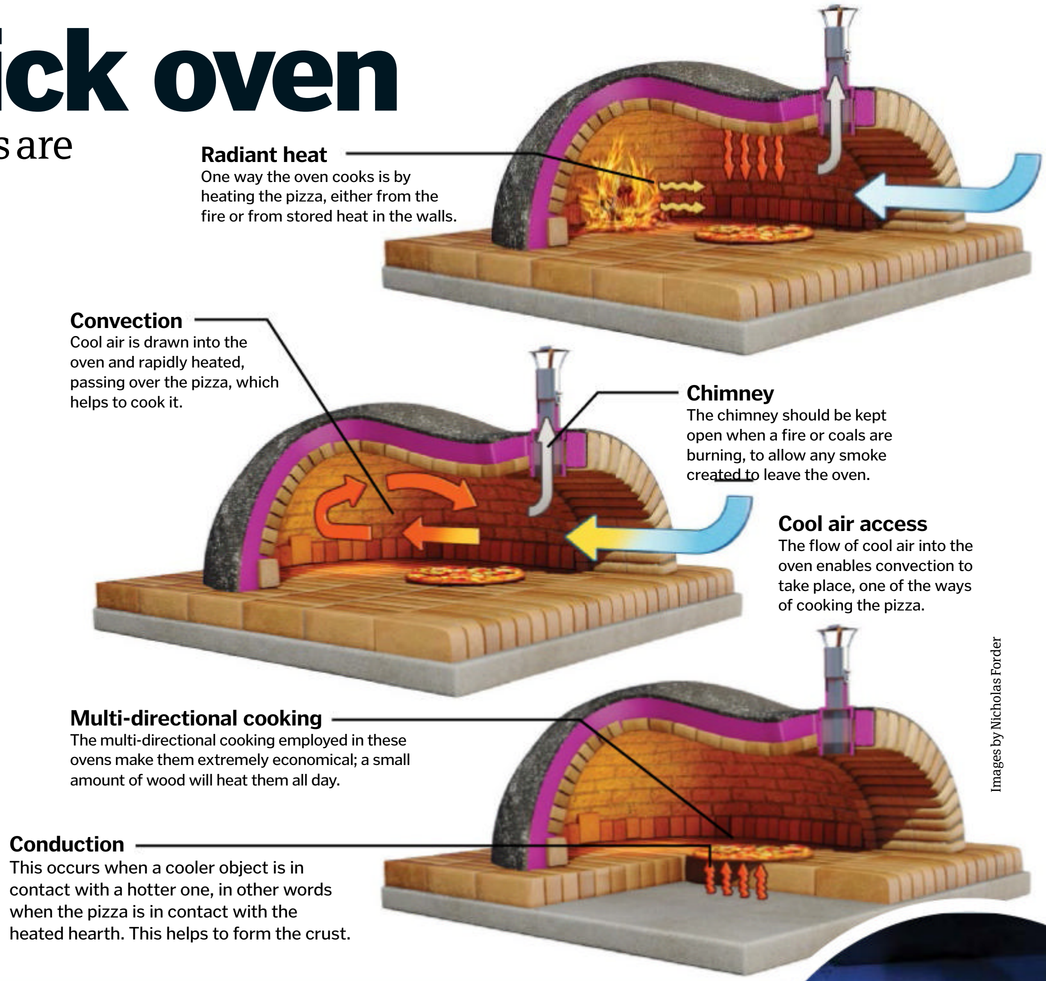
© Dreamstime; Freevectormaps.com

Inside a brick oven

Find out why these ancient ovens are still the best way to cook pizza

It's impossible to replicate the unique, savoury taste that wood-burning brick ovens give to pizzas. It is thought that this form of cooking has been around for at least 3,000 years, and was once the only means of baking bread. Examples of this type of oven have even been excavated in ancient Pompeii. In Italy, families tended to have their own brick ovens, which is the foundation of the country's modern pizza industry.

To cook a pizza, the first thing you need is a fire within the oven. While this burns, it's important to keep the door and chimney flue open. The oven's interior absorbs and retains the heat created by the fire, and should be left to do this until the oven chamber is white hot. The fire can then be left to die down, and the door and chimney can be closed so the oven reaches an even temperature. The oven is now ready to cook pizza, which typically takes less than two and a half minutes – much quicker than gas or electric powered ovens. Because they are able to retain heat for a long time, brick ovens can be one of the most efficient and economical methods of cooking.



Radiant heat
One way the oven cooks is by heating the pizza, either from the fire or from stored heat in the walls.

Convection
Cool air is drawn into the oven and rapidly heated, passing over the pizza, which helps to cook it.

Chimney
The chimney should be kept open when a fire or coals are burning, to allow any smoke created to leave the oven.

Cool air access
The flow of cool air into the oven enables convection to take place, one of the ways of cooking the pizza.

Multi-directional cooking
The multi-directional cooking employed in these ovens make them extremely economical; a small amount of wood will heat them all day.

Conduction
This occurs when a cooler object is in contact with a hotter one, in other words when the pizza is in contact with the heated hearth. This helps to form the crust.

Images by Nicholas Forder

The secrets of safes

How prehistoric fossils can keep your possessions from harm

Banks use vaults instead of safes as they are integrated into the building, whereas a safe itself can be stolen

The term "a safe" was first used in the 1800s to describe a chest or cupboard that was not only thief resistant, but could also fend off flames and withstand falling buildings. The modern-day safe still upholds this mantle and has been designed to endure most types of attack.

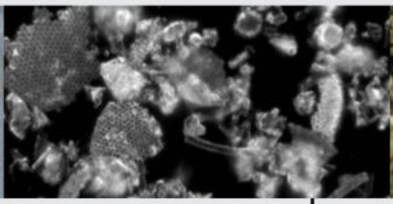
Today, safes are typically constructed with two pieces of steel that sandwich a specially treated piece of concrete. This concrete has diatomaceous earth (containing prehistoric fossils) and vermiculite added to it, to enhance its strength. There are now a number of different types of lock available to operate a safe's door. Modern day technology such as retina or fingerprint scanning is available, but still comes at a hefty premium.

The most commonly used lock is still the combination variety, which typically requires the user to enter three different numbers to gain access to the treasures that are inside. But the chance of guessing this combination is one in 941,094, making it extremely hard to crack.

How a safe resists damage

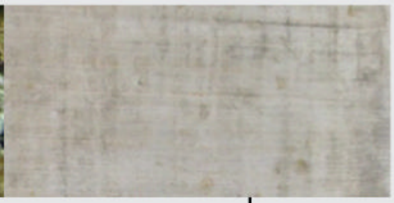
See the materials that make a safe both fire proof and thief resistant

Steel
Two thick pieces of steel sandwich together the specially treated concrete layer.



Diatomaceous earth
This earth is rich in silica, which gives the concrete an incredibly high melting point of over 1,700°C (3,902°F), helping it withstand high temperatures without becoming structurally compromised.

Vermiculite
Vermiculite is also mixed in with the concrete which has a popcorn-like structure that helps prevent heat from damaging the safe's contents.



Concrete
Although steel is incredibly tough on its own, the addition of a concrete layer makes the overall structure much harder to infiltrate, especially with a drill.

DID YOU KNOW? *Guitarist Eddie Van Halen used a power drill with his guitar in the Van Halen song "Poundcake"*

Your guide to household drills

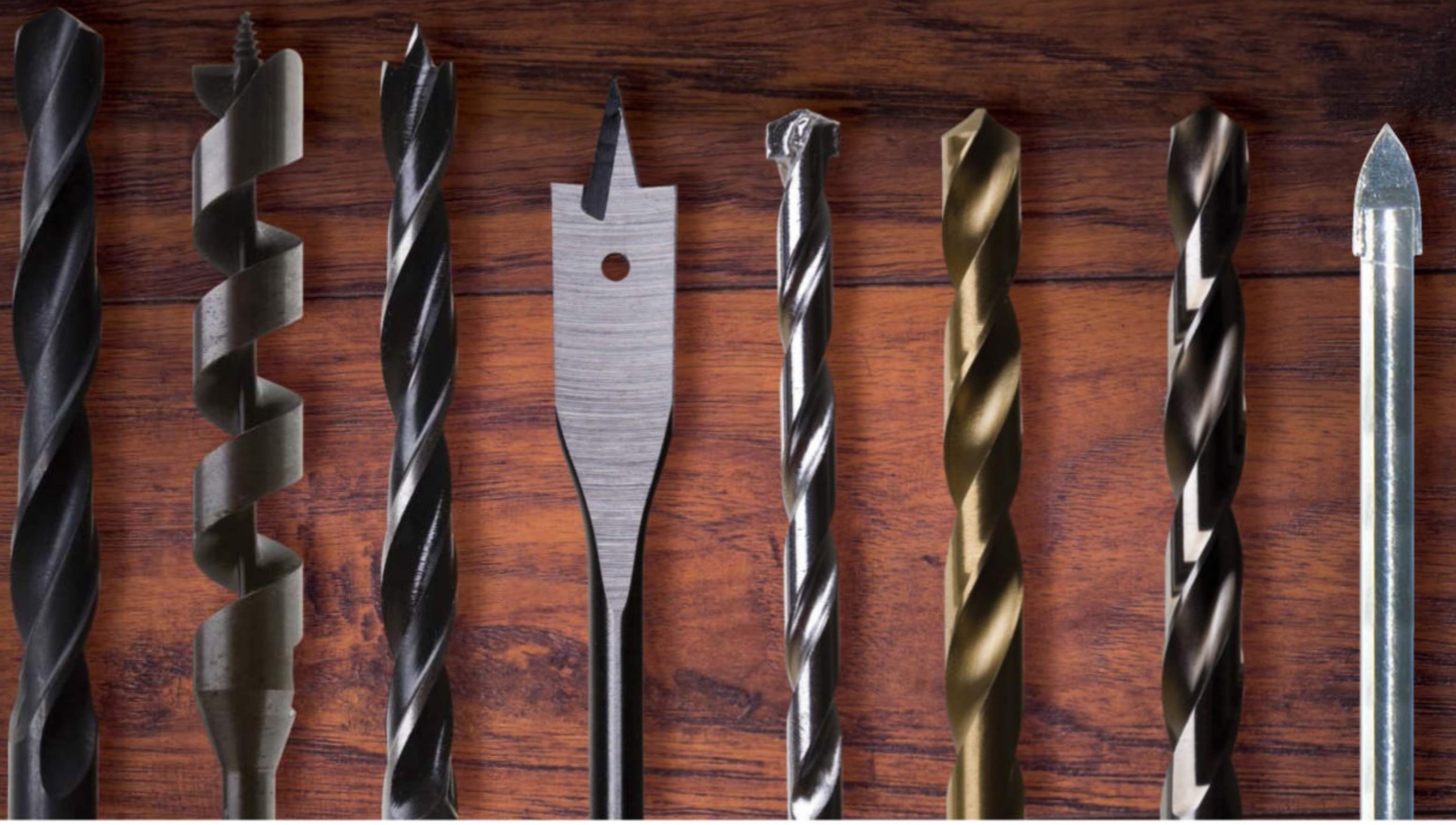
Learn why selecting the correct drill bit lets you make the right hole in the right place

Rudimentary drills were invented by early humans so they could bore holes in materials. These days, the ability to drill provides society with a range of benefits, from accessing petroleum to curing toothache. The technology behind household drills is very simple in design. Squeezing the trigger initiates an electric motor, causing the chuck to spin the drill bit, which cuts into the target material.

Despite the simple design, inefficient drilling can still create problems, potentially damaging the material or the user in the process.

This highlights the importance of using the correct drill bit, which is where the real technological advancements lie. Today, there is a plethora of drill bits on the market in a variety of shapes and sizes. Most have either a tapered or sharpened end that cuts away material and an auger (a spiral screw thread), that removes the drilled material from the hole. Numerous speciality drill bits also exist. These have a unique design and specialised function, such as the cone drill bit, which can drill different-diameter holes in thin materials.

Certain geometric characteristics play a role in how drill bits cut through a material. The spiral, or rate of twist, is responsible for moving the drilled material from the hole and is varied depending on the required cutting speed. The material to be drilled determines the point angle, which is the angle formed at the bit's tip. Harder materials need a larger angle in order to drill them, while softer materials need a sharper angle. It's vital the correct one is used; this will reduce the risk of the drilled hole being uneven or in the wrong location.



HSS-Rolled The most common kind of drill bit, ideal for use on plastic, wood and metal.

Spur auger Similar in function to spade drill bits, they leave neater holes and require less torque to spin, hence they are a popular choice for hand-powered drills.

Brad-Point This drill bit offers precise drilling in all types of wood, due to its centring tip.

Flat/Spade With this drill bit it's possible to drill cleanly and accurately through wood. They are also easy to sharpen and inexpensive to buy.

Masonry As its name suggests, this bit is used on concrete and bricks. They have a tungsten carbide coating for maximum durability.

HSS-Titanium This bit will quickly drill a variety of metals, including silver, bronze, iron and copper.

Multipurpose This drill bit works well for most tasks encountered domestically. It has a centring tip for added precision, along with tough, diamond-ground edges.

Glass and tile Designed to work with soft tiles, ceramic porcelain and standard glass, this drill bit has a tungsten carbide head for superb durability.

© Dreamstime

Skyscrapers that don’t cast shadows

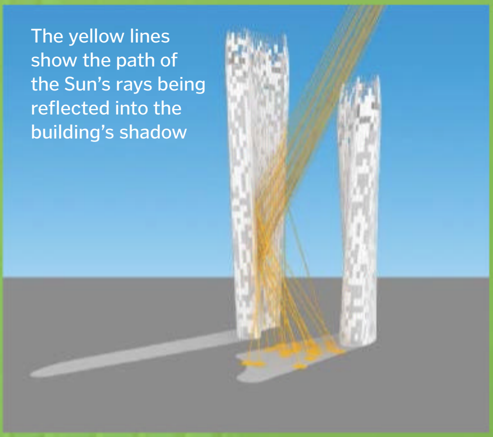
Smart structures work together to reflect sunlight into the shade

In the race to build taller skyscrapers, large areas of cities are being plunged into shadow as a result. To bring a bit of sunshine back into the lives of the people below, global architecture firm NBBJ has designed the first shadowless building. It used computer modelling and algorithms to create a pair of towers that work together to reduce shadows on the ground by 60 per cent. The concept is intended to be built in Greenwich, London, but the firm says its software can be used to design similar skyscrapers for cities all over the world.

The shadowless structures could be two of the 250 new skyscrapers planned for London

DID YOU KNOW? *The tallest skyscraper in the world is the Burj Khalifa in Dubai, which stands at 829.8 metres high*

The glass structures will brighten up the shaded busy streets below



The yellow lines show the path of the Sun's rays being reflected into the building's shadow

Shadowless structures

To minimise the amount of shade below tall buildings, NBBJ's architects have proposed a clever mirroring system. The curved glass surface of the northernmost building reflects sunlight down into the shadow of the southern tower. The carefully shaped glass will even be able to redirect the light to fill in the shadow as it moves throughout the course of the day. The towers designed for London are wider at the top than at the bottom to reflect more light when the Sun is higher in the sky during the summer months. However, if designed for other locations, the buildings may need to be less top-heavy to account for the climate and Sun's position. To ensure the enormous mirrors do not magnify the Sun's rays to fry the people and objects below, the glass also diffuses as well as reflects the light for a softer, more natural effect.

PETRONAS
SYNTIUM
BlackBerry

Mercedes 2015 is not the only fast part of the team; they have also been achieving the fastest pit stops with an average of 23.6 seconds

Mercedes F1 W06 hybrid

Discover the technology that makes Mercedes' 2015 entry the greatest hybrid Formula One has ever seen

Lewis Hamilton has had incredible success with Mercedes' 2015 F1 car, finishing on the podium in the first nine Grand Prix

In 2014, the governing body of Formula One decided that it was time to introduce hybrid engines. This changed F1 forever; the 2.4-litre V8 gas-guzzling monsters were replaced with the much more economical 1.6-litre V6. This was hugely challenging for all the teams in F1, but none have dealt with the change as successfully as Mercedes. Their 2014 concoction dominated F1, but rather than resting on their laurels they set about making improvements immediately at the conclusion of the season.

Upgrades were implemented in almost every part of the car, including the mechanics, structure, aerodynamic properties and weight-saving technology. They have looked to squeeze every possible ounce of performance out of the design, which has clearly paid dividends if 2015's race results are anything to go by. The two drivers, Lewis Hamilton and Nico Rosberg, lost only 65 points out of a possible 516 in the first 12 races of the season. They took ten wins, 12 pole positions and eight fastest laps, not to forget seven one-two finishes.

At the time of writing it seems very unlikely that another team will be able to catch up to Mercedes. Another F1 driver / manufacturer double beckons for the German giants.

DID YOU KNOW? *Mercedes recently won the constructors' championship at the 2015 Russian Grand Prix*

Mercedes' hybrid technology

As the age of the hybrid engine continues, Mercedes are constantly researching new ways to boost power and performance while remaining within Formula One's limits. The current engine produces the same power output as its V8 predecessors, but incredibly uses only two thirds of the fuel. It boasts a 40 per cent thermal efficiency compared to the 29 per cent achieved in Mercedes' previous models, which has led some to class this engine as the most efficient gasoline powertrain ever built.

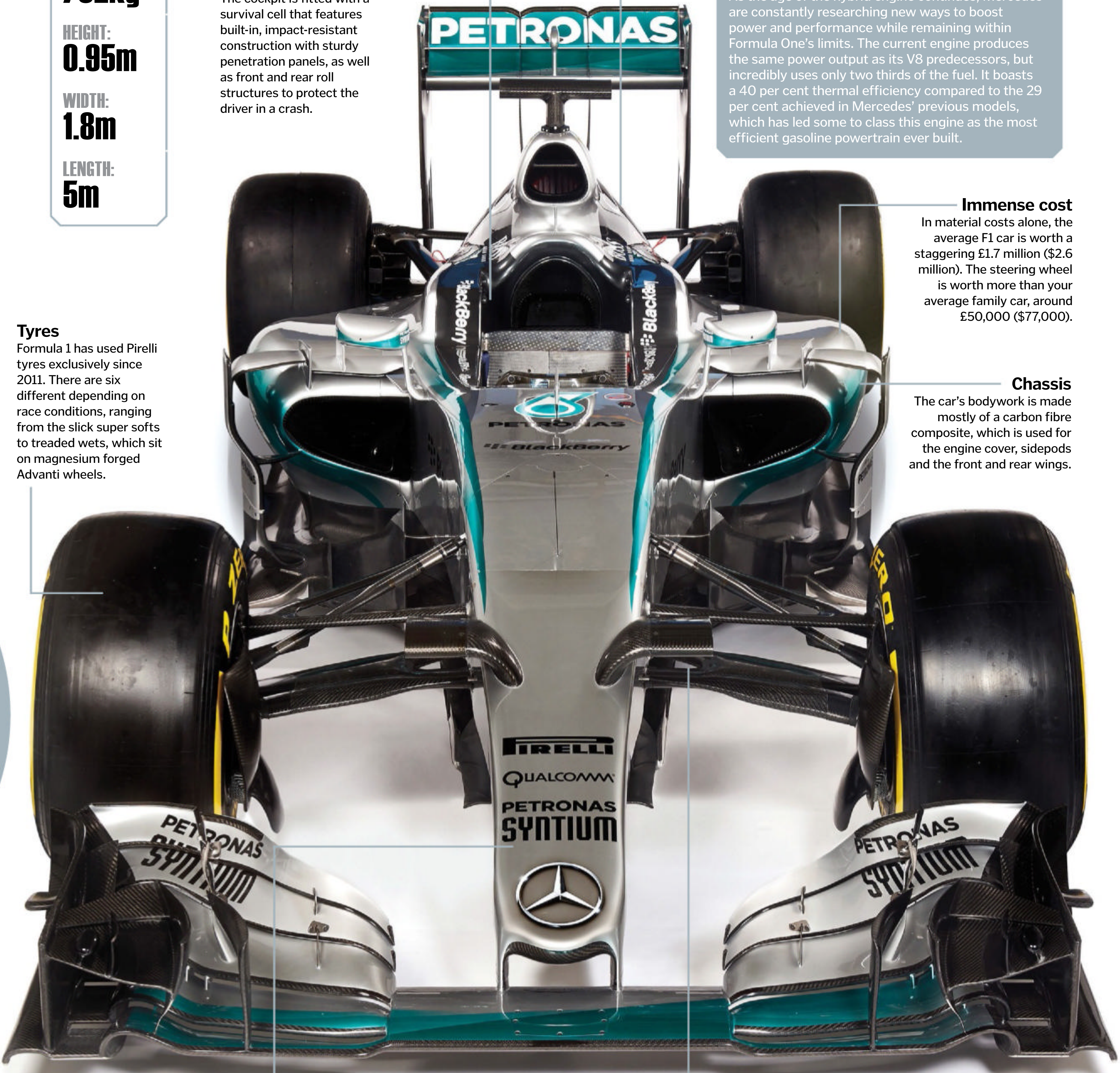
STATS

WEIGHT:
702kg

HEIGHT:
0.95m

WIDTH:
1.8m

LENGTH:
5m



Prioritised safety features
The cockpit is fitted with a survival cell that features built-in, impact-resistant construction with sturdy penetration panels, as well as front and rear roll structures to protect the driver in a crash.

Hybrid engine
The PU106 Hybrid Turbo is a 1.6 litre V6, capable of producing 15,000 RPM in its mid-mounted, rear-wheel drive format.

Immense cost
In material costs alone, the average F1 car is worth a staggering £1.7 million ($2.6 million). The steering wheel is worth more than your average family car, around £50,000 ($77,000).

Tyres
Formula 1 has used Pirelli tyres exclusively since 2011. There are six different depending on race conditions, ranging from the slick super softs to treaded wets, which sit on magnesium forged Advanti wheels.

Chassis
The car's bodywork is made mostly of a carbon fibre composite, which is used for the engine cover, sidepods and the front and rear wings.

Front nose
One of the most noticeable changes from Mercedes' 2014 model is in the front nose. It is now shorter and stiffer than ever before, which helps protect the driver in a collision.

Hi-tech suspension
Both the rear and front suspension are fitted with carbon fibre wishbone and pushrod activated torsion springs and rockers, providing the most efficient and smoothest ride possible for the driver.

The Doomsday Seed Vault

Welcome to the Swiss bank of the agricultural world

The art installation in the entrance is lit up at night

Deep within the Arctic Circle, on the frozen island of Spitsbergen in the Norwegian Svalbard archipelago, is a giant vault. It's something you'd half expect to find in a Bond movie: set 120 metres (394 feet) inside a mountain, it's the site of an old coal mine and boasts some formidable security features that include reinforced concrete walls, dual blast-proof doors, motion sensors and airlocks. The island's remote location, just 1,300 kilometres (808 miles) from the North Pole, its inhospitable climate and treacherous terrain make monitoring human activity in the area relatively easy. The 1,750 banks from around the world, which have made hundreds of thousands of deposits to this vault, can sleep easy knowing their investments are secure. But this is no safe house for cash or gold, or a financial institution of any kind.

The Svalbard Global Seed Vault is a giant repository for the world's seed crops, an effort on the part of several multinational corporations and governments to protect future crop diversity. This includes the Bill and Melinda Gates Foundation along with a conglomerate of corporations with agricultural interests known as the Global Crop Diversity Trust, and the Ministry of Agriculture and Food on behalf of the Norwegian government.

Svalbard is an ideal choice for the vault's location as a kind of fail-safe, should worldwide seed banks fail. It's remote, but has good infrastructure and a ready supply of coal to power the facility. The sandstone the vault is set into is low in radiation and stable, plus it's very cold, so the rooms will remain cold even if the refrigeration units fail.

The entrance is the only part of the Svalbard Global Seed Vault that stands above ground

How does it protect our food?

Last year, around 10,000 new varieties of food crop seeds were added to the Svalbard Global Seed Vault from over 100 countries all over the world, bringing the total number of seed samples contained within the vault to over 835,000. But if these are being already grown in the countries they're native to, what's the point in a worldwide seed vault?

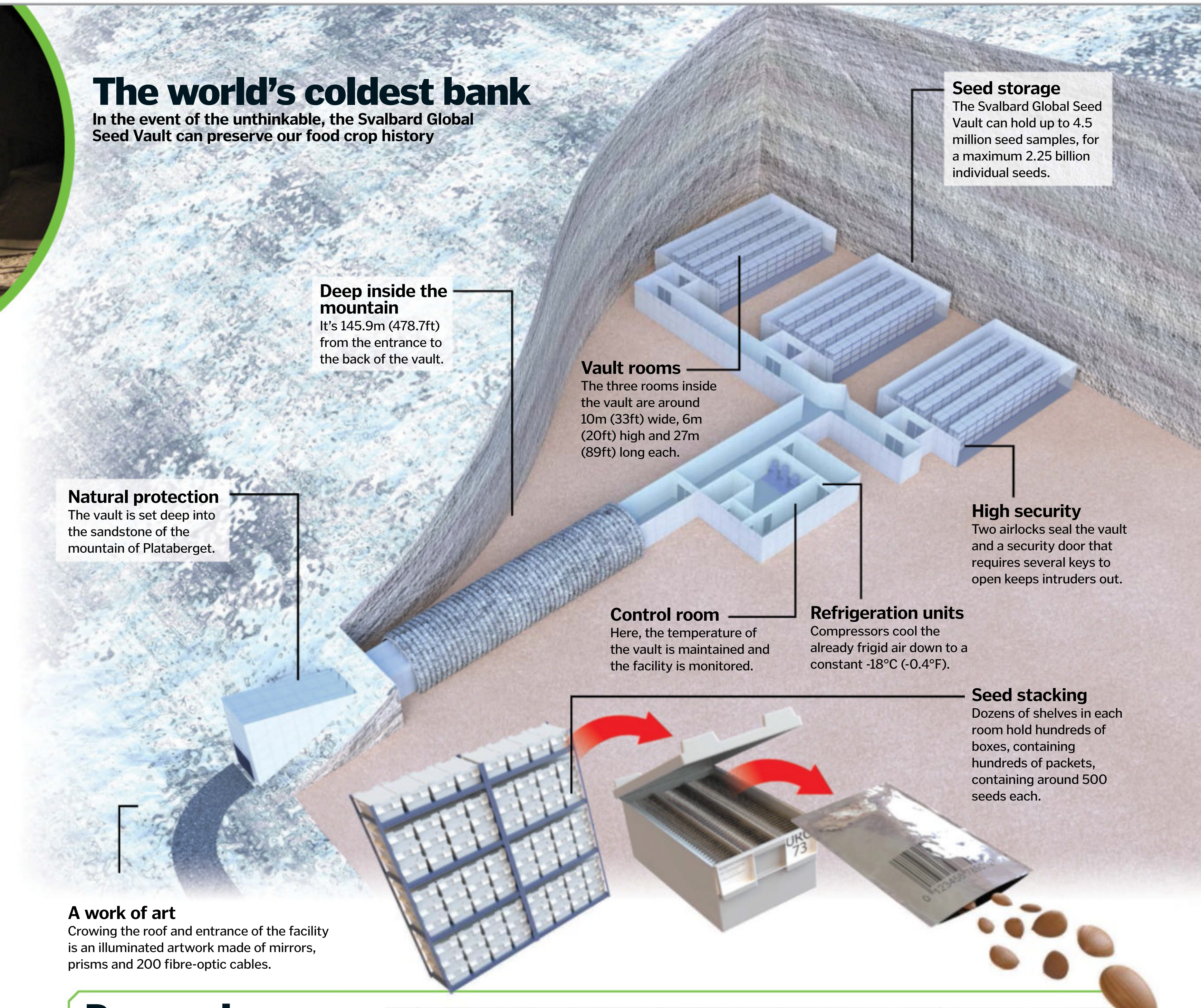
In the event of natural disaster or civil war destroying crops, the seed vault provides a back-up for the seed banks in that country – and we've already seen it prove its worth as a contingency: the Philippines national seed bank was damaged by flooding and then fire, while Afghan and Iraqi banks have been wiped out by wars in those regions. Anyone who wants access to the seeds, such as plant breeders or researchers, must go through the seed bank that made the deposit: even though the vault is managed by the Norwegian government, the depositors retain sole ownership of the seeds.

Heat-sealed, four-ply aluminium bags are used to store and preserve each seed sample

DID YOU KNOW? *In 2005, a 2,000-year-old Judean date palm seed from Herod's palace in Israel was grown into a plant*

The world's coldest bank

In the event of the unthinkable, the Svalbard Global Seed Vault can preserve our food crop history



Seed storage
The Svalbard Global Seed Vault can hold up to 4.5 million seed samples, for a maximum 2.25 billion individual seeds.

Deep inside the mountain
It's 145.9m (478.7ft) from the entrance to the back of the vault.

Vault rooms
The three rooms inside the vault are around 10m (33ft) wide, 6m (20ft) high and 27m (89ft) long each.

Natural protection
The vault is set deep into the sandstone of the mountain of Plataberget.

High security
Two airlocks seal the vault and a security door that requires several keys to open keeps intruders out.

Control room
Here, the temperature of the vault is maintained and the facility is monitored.

Refrigeration units
Compressors cool the already frigid air down to a constant -18°C (-0.4°F).

Seed stacking
Dozens of shelves in each room hold hundreds of boxes, containing hundreds of packets, containing around 500 seeds each.

A work of art
Crowing the roof and entrance of the facility is an illuminated artwork made of mirrors, prisms and 200 fibre-optic cables.

Preserving our food future

Duplicate samples of seeds from national seed banks are stored in sealed aluminium bags that exclude moisture, then shelved in itemised containers, the contents of which are recorded and held on a database maintained by the Norwegian authorities. The bedrock that surrounds the vault is a temperature of minus-three degrees Celsius (27 degrees Fahrenheit), although the facility is kept even colder by refrigeration units that chill the seeds to minus-18 degrees Celsius (minus-0.4 degrees Fahrenheit). The island of Spitsbergen is tectonically inactive and even if the ice caps melted, the site lies high enough to remain above sea level. Under these conditions, seeds will remain viable for hundreds or even thousands of years.

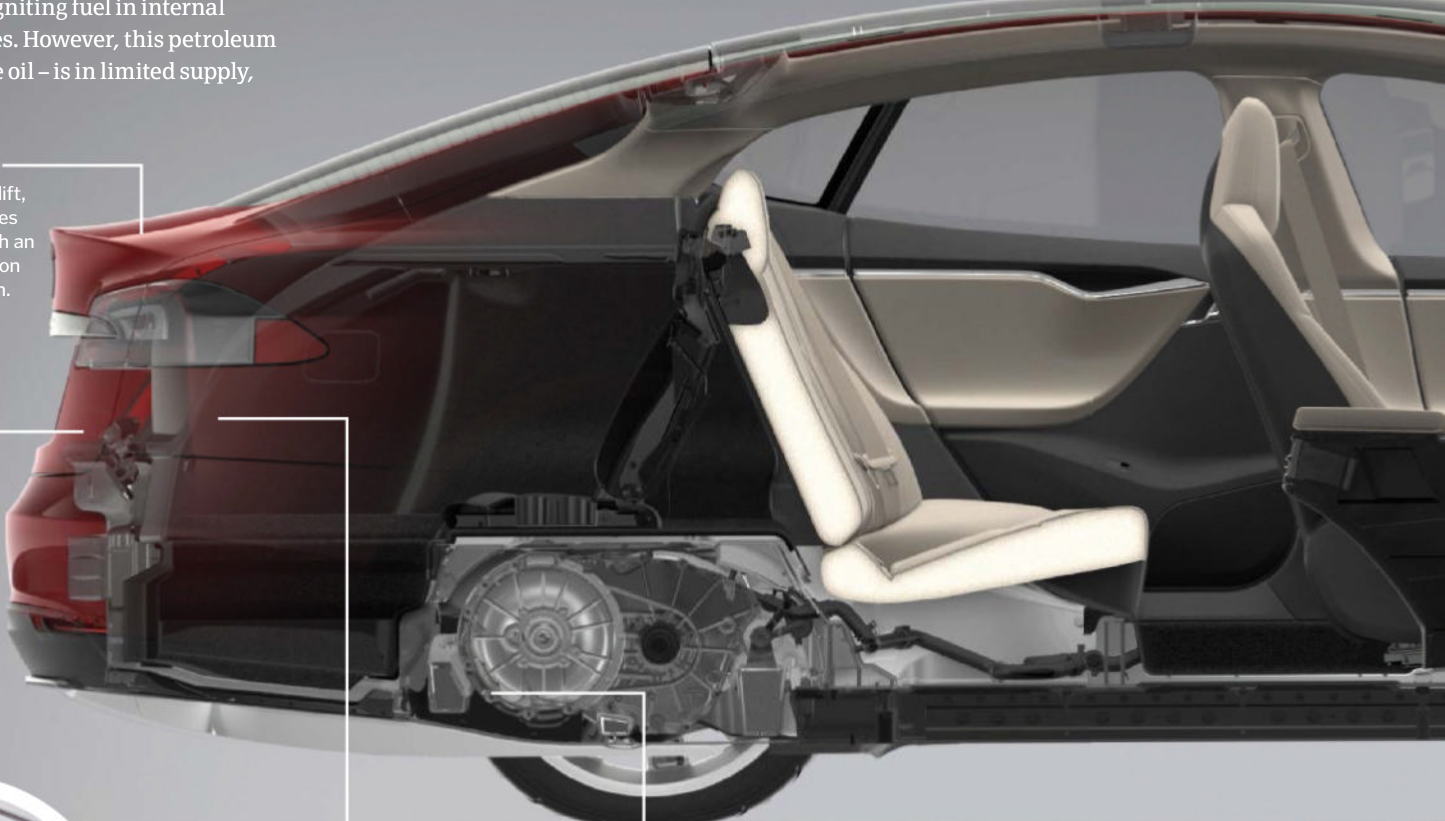
The construction of the vault was funded entirely by the Norwegian authorities

© Alamy; Rex Features

INSIDE THE TESLA MODEL S

They're the most talked-about electric car manufacturer in the world, but just what makes Tesla Motors so innovative?

The concept of an electric car is not a new idea. Manufacturers were building them as far back as the 19th century, with Porsche building their first car, the electric P1, in 1898. Despite its deep-rooted foundation with vehicles, electricity was never substantially developed enough to become the power of choice for cars. Instead, vehicles have been powered by igniting fuel in internal combustion engines. However, this petroleum – a product of crude oil – is in limited supply, prompting car manufacturers to look at alternative forms of power, such as hydrogen and hybrid systems. Electricity has once again come to the fore, and California-based Tesla Motors is leading the charge for this viable, greener technology in our modern world. Unlike other manufacturers, Tesla (led by renowned entrepreneur and CEO Elon Musk) is a relatively new company that specifically produces electric vehicles. Their innovation and commitment to making futuristic cars has ensured that this small Californian company has garnered an impressive reputation across the globe, and we will show you why…



Auto-close boot
Boots can be heavy to lift, but the Model S provides the perfect answer with an auto-open/close function at the touch of a button.

Rear-view camera
Mounted above the rear licence plate, a camera passes a live feed through to the large interior screen, so the driver can see behind the car when reversing.

More storage space
With no engine to speak of, the Model S actually has two luggage storage compartments: one in the front of the car under the conventional 'hood', and the other in the rear.

> "Tesla Motors is leading the charge for this viable, greener technology"

Regenerative brakes

As well as using electricity, the Model S is also able to generate it while driving through town. When a driver lifts off the accelerator pedal, gentle braking is automatically applied, and the energy harvested by the brakes is then fed back into the motor to reuse. This is a key component in helping the Model S to maintain its exceptional range.

Software updates

One of the most creative innovations over a conventional car is Tesla's use of software updates. This is all done over-the-air, meaning cool new features can be added to the Model S overnight. An example of this is the addition of the 'creep' function when releasing the brake pedal in traffic, which was added after Tesla consulted with Model S owners on how to improve the driving experience.

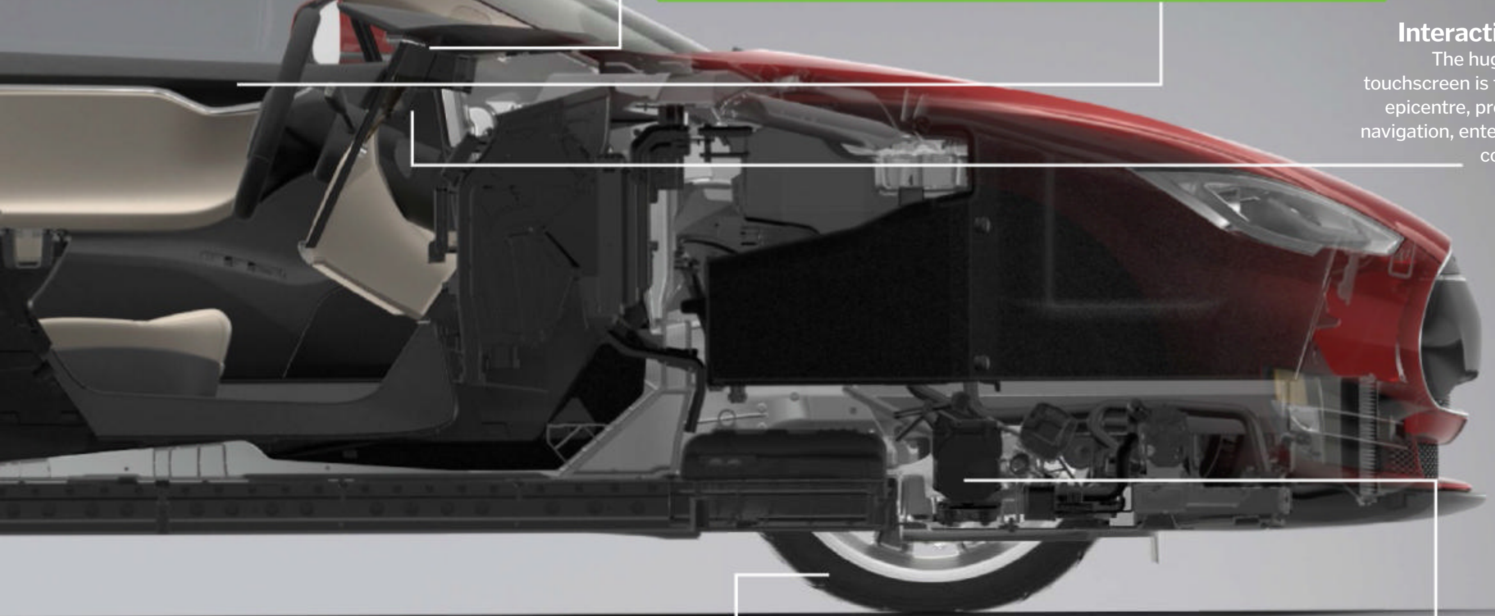
No more keys!

The Model S doesn't use a conventional car key as we know it. Instead, owners are presented with a small fob – sculpted to mimic the shape of the car itself – which has a built-in transmitter that talks to the car via onboard sensors. This means an owner only needs to have the key on their person and, when they approach the car, the door handles pop out and the car is ready to start.

Preconditioning

Thanks to the intuitive Tesla Model S app, owners can precondition the on-board climate of their vehicle remotely, so the car reaches the perfect temperature by the time they enter.

Climate On
TURN OFF
Interior Temperature: 94°F
70°



Interactive interface

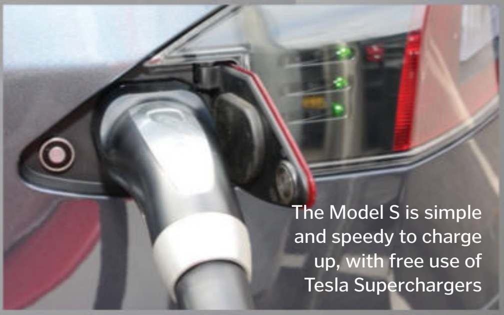
The huge dash-mounted touchscreen is the technological epicentre, providing access to navigation, entertainment, HVAC controls and more.

Air suspension

Want to lower the Model S for sportier handling or raise it to clear a steep driveway? This can be done with a tap of the dash-mounted touchscreen.

Quiet tyres

With a noisy engine replaced by a beautifully silent motor, the Model S glides along the road with virtually no audible soundtrack. From inside the car, the only noise that remains (with the radio switched off) is rolling road noise. To combat this, ContiSilent tyres from Continental are used, which have an extra layer of foam inside to reduce the noise it produces when rolling along a surface.



The Model S is simple and speedy to charge up, with free use of Tesla Superchargers

© Tesla

Inside the Tesla factory

Here's how the innovative Model S is put together in Fremont, California

Tesla Motors can lay claim to producing some of the most innovative and technically advanced electric vehicles on the planet. Currently, Tesla produce one car – the Model S – which is available with a variety of power and drive options, however, a Model X SUV is planned for 2016. This Model X will be manufactured alongside the existing Model S from Tesla's main factory in Fremont, California.

The facility was once home to General Motors and Toyota, producing half a million vehicles per year. Tesla Motors purchased the premises on Fremont Boulevard in 2010. They transformed the building into a factory that's as technologically advanced as the cars that roll out of it, all on a site that covers an area of 492,000 square metres (5.3 million square feet), used for both manufacturing and office space. Old assembly equipment was torn out and robots were installed that can perform complex functions, from assembling the chassis to welding and laser-cutting parts. Each one is named after an *X-Men* character, as they have the 'superpowers' to lift and manoeuvre entire cars with ultimate precision.

The factory floor itself is split down into five sections: stamping, assembly, body, paint and plastics. Every part of the Model S build process is carried out at the factory in California, from the early panel beating to final test-driving. State-of-the-art technology used by Tesla in the production of its cars also means high efficiency, reducing its carbon footprint. This includes basic measures, such as replacing fluorescent lights with energy-saving LED lamps, all the way to using ultrasonic waves inside the car instead of wasting gallons of water for a leak test. They also use powder coatings for the primer and clear coat layers instead of traditional liquid paints (which contain harmful compounds), another modification that helps lower emissions.

The addition of advanced robots and conveyors enables the factory to process one million battery cells every day. Soon it is hoped that the robots will also be able to install the battery packs in the cars, which will relieve factory workers of one of the most labour-intensive jobs in the process. Currently, Tesla can produce up to 100,000 vehicles annually. Not bad for a company that is less than 15 years old.

A robot named Xavier lifts cars down to the floor so the other 'superhero' machines can assemble them

From factory floor to your driveway

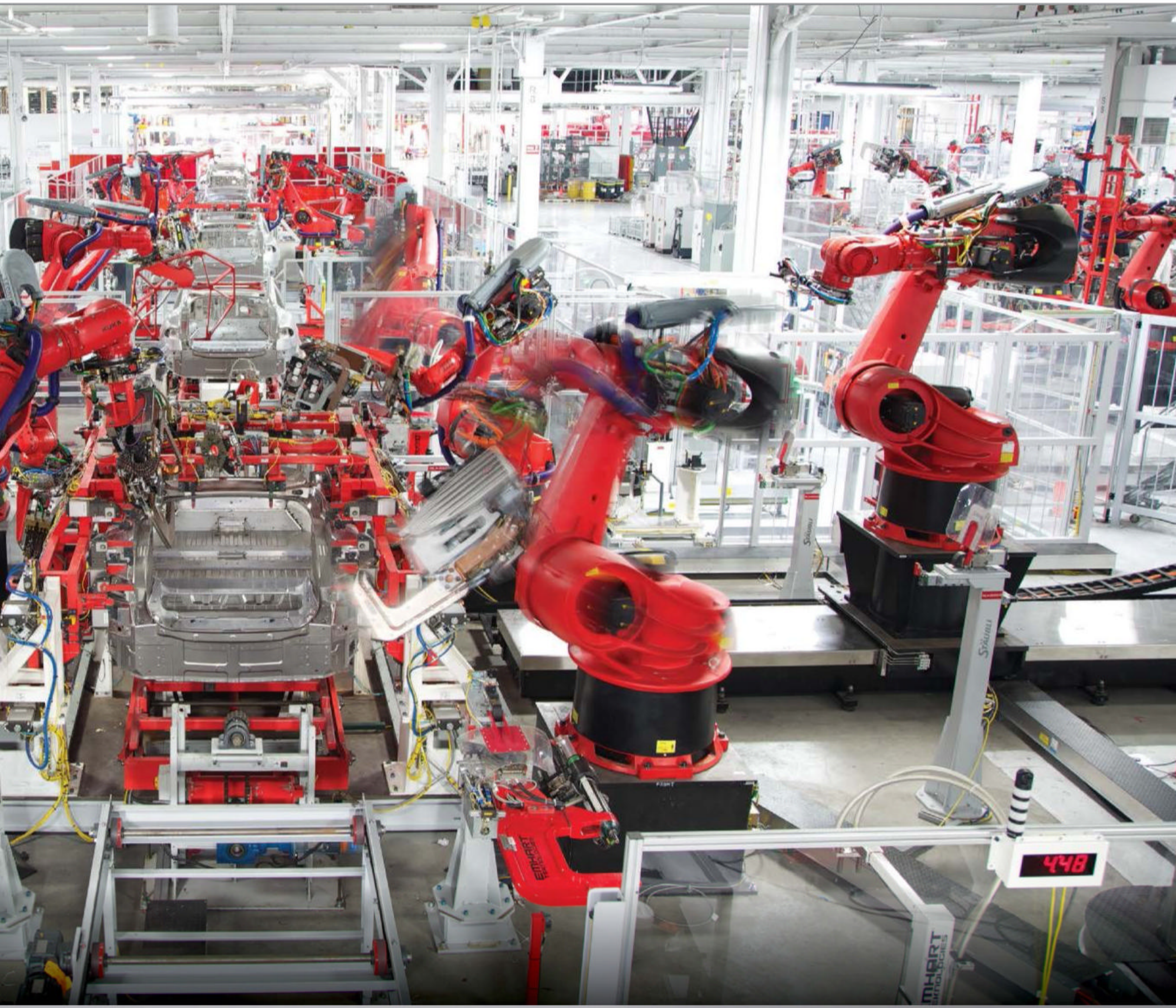
Discover what it takes to create a Tesla Model S

1 Stamping Aluminium sheets are machine stamped into doors, roofs and hood panels using a hydraulic press.

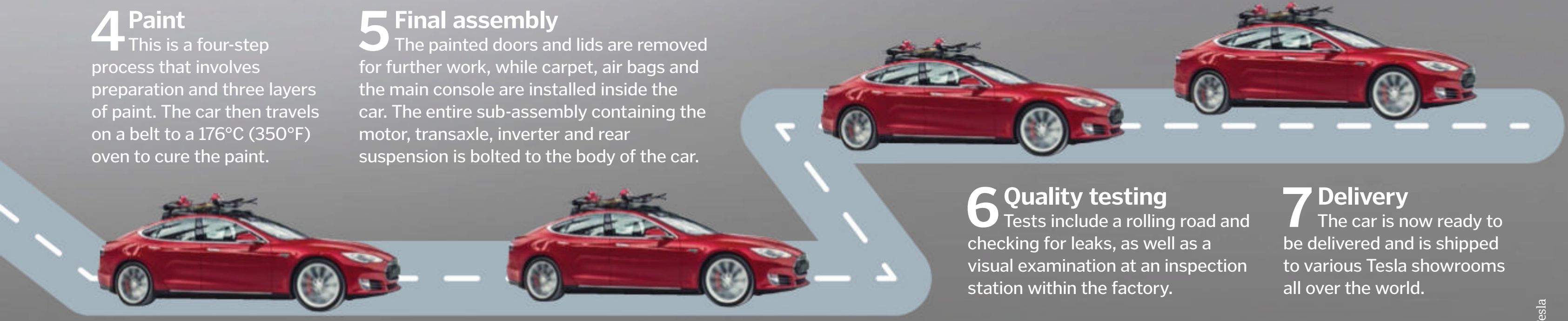
2 Sub-assembly Groups of workers on the production line join the stamped pieces together as sub-assemblies, while outer panels are welded to the car's inner structures for strength and safety.

3 Framing Robotic arms take the sub-assemblies and begin gluing, welding and riveting. All doors and lids are hung on the main frame, and the entire primary structure is checked for imperfections.

DID YOU KNOW? *Tesla's first production vehicle was the Roadster, which looks similar to the Lotus Elise but shares 6% of parts*



> *"Old assembly equipment was torn out and robots were installed"*



4 Paint
This is a four-step process that involves preparation and three layers of paint. The car then travels on a belt to a 176°C (350°F) oven to cure the paint.

5 Final assembly
The painted doors and lids are removed for further work, while carpet, air bags and the main console are installed inside the car. The entire sub-assembly containing the motor, transaxle, inverter and rear suspension is bolted to the body of the car.

6 Quality testing
Tests include a rolling road and checking for leaks, as well as a visual examination at an inspection station within the factory.

7 Delivery
The car is now ready to be delivered and is shipped to various Tesla showrooms all over the world.

© Tesla

Automated features

How the Model S can switch lanes and park by itself

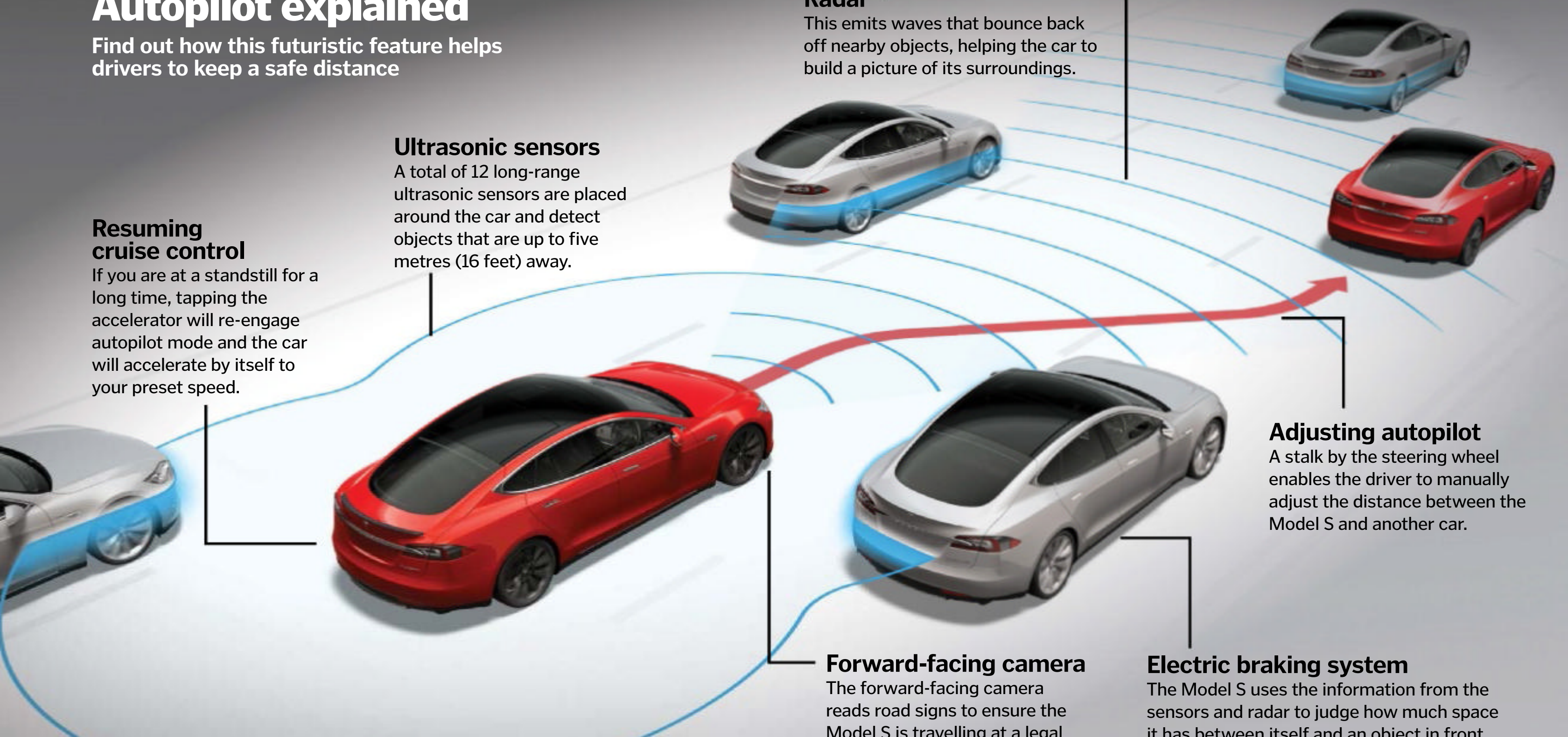
Although not quite a driverless car, the Model S does boast an array of automated features including autopilot, lane change assist and automated parking. The most revolutionary of these, autopilot, works by utilising a forward radar, 12 long-range ultrasonic sensors positioned around the car, a forward-facing camera and a digitally-controlled electric braking system.

The camera reads road signs and checks for objects in front of the Model S' projected line, while the radar and ultrasonic sensors constantly sense five metres (16 feet) around the car to check for objects such as cars in traffic. The data is fed to the car's engine control unit (ECU), which determines what lane or path the Model S needs to take. The idea is to take the strain out of situations such as congestion, offering increased comfort for the driver.

Similarly, the software and hardware is able to steer to keep the Model S within a designated lane, or even change lanes with just a tap of a turn signal, all while managing speed by reading road signs. Automatic parking is also possible under the same technology. The car will notify the driver when it detects an available parking space and be capable of smoothy manoeuvring into it.

Autopilot explained

Find out how this futuristic feature helps drivers to keep a safe distance



Radar
This emits waves that bounce back off nearby objects, helping the car to build a picture of its surroundings.

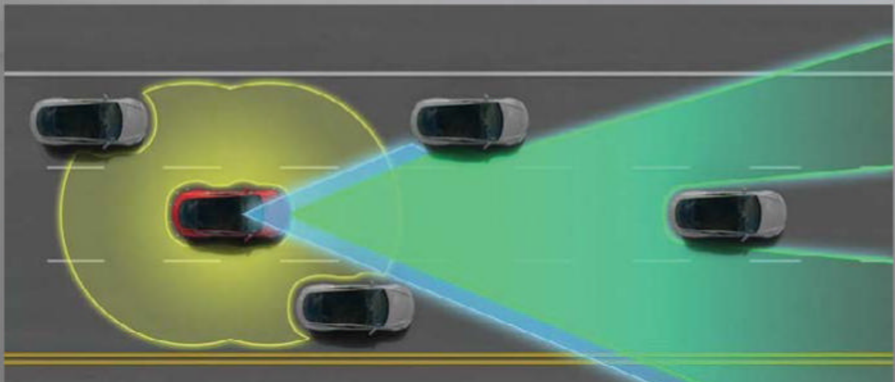
Ultrasonic sensors
A total of 12 long-range ultrasonic sensors are placed around the car and detect objects that are up to five metres (16 feet) away.

Resuming cruise control
If you are at a standstill for a long time, tapping the accelerator will re-engage autopilot mode and the car will accelerate by itself to your preset speed.

Adjusting autopilot
A stalk by the steering wheel enables the driver to manually adjust the distance between the Model S and another car.

Forward-facing camera
The forward-facing camera reads road signs to ensure the Model S is travelling at a legal speed at all times.

Electric braking system
The Model S uses the information from the sensors and radar to judge how much space it has between itself and an object in front. When that space reduces, the brakes are automatically applied.



The forward-facing cameras and sensors can scan up to 160m (525ft) of the path ahead

The Speed Assist function makes sure that the Model S keeps within the speed limit of the road

DID YOU KNOW? *Tesla CEO Elon Musk is also the founder of advanced spacecraft and rocket manufacturer SpaceX*

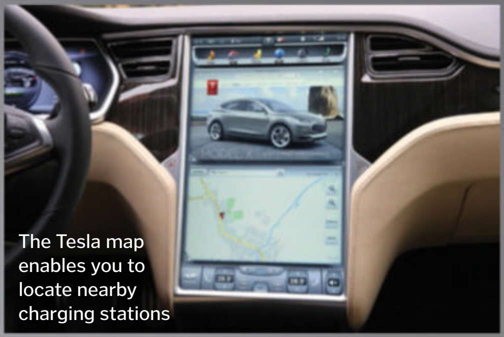
In the driver's seat

It may look like a conventional car from the outside, but the interior is laden with next-gen tech

Aside from there being no transmission tunnel running through the middle of the car (or even a gear stick for that matter) offering up more space, the interior is akin to that of a conventional vehicle. There are two seats up front, a rear bench in the back, and even an extra two rear-facing child seats in the boot space, should you wish to pay the optional £2,500 (nearly $4,000). However, the genius of the Model S lies with the huge 43-centimetre (17-inch) touchscreen in the centre of its dashboard. This interface is the main control hub for the entire car: the driver operates the touchscreen to access a variety of menus and settings, which control everything from opening the sunroof to providing satellite navigation.

On purchase of a vehicle, an owner is encouraged to download the Tesla Model S app, which lets you precondition the car's climate ready for your arrival, as well as flash the headlights or honk the horn – useful if your Tesla is parked in a busy multistorey car park. The app also provides a live location of the car's whereabouts via a satellite view powered by Google, ideal in the event of the car being stolen. Added to this, the app remotely notifies the owner when the Model S has finished charging, aiding the efficiency of the car in fitting in with the driver's day-to-day lifestyle.

The touchscreen is the focal point of the Model S' interior, negating the need for a plethora of controls



The Tesla map enables you to locate nearby charging stations

Q&A with Tesla UK's Georg Ell, country director

What do you think is the biggest advantage of owning a Tesla right at this moment?
It's the opportunity to be part of something that is shaping the future of motoring. It's future-proof, fun, exciting and safe at the same time. In 200 years from now, people will say Tesla was the [point] where we, as a planet, decided to turn our back on internal combustion engines that poison our air and damage the atmosphere. The quality of air is so bad that 50,000 people die per year due to poor air quality. Tesla is leading the change: people will soon look at motoring today much in the same way as when they think back to a time when smoking on aeroplanes and in pubs was permitted. It's a slice of the future, today.

How will you ensure a Model S is still on the road in ten years' time?
Because there are so few elements to a Tesla. It's more viable than a conventional car as the system is simpler: all that's left on our car when stripped back is a single moving part – the motor. This makes it far more easier to maintain financially than a conventional internal combustion-engined vehicle.

Lithium-ion batteries are known to deteriorate after a number of charges. What is Tesla doing to combat this?
Tesla currently gives an eight-year, unlimited mileage warranty on the battery and drivetrain. We're also developing a drivetrain that can achieve a million miles! Batteries will have an element of degradation, about one per cent per 10,000 miles, but our battery capacity is improving year-on-year by five per cent. We are also working on a system where Tesla owners can pay to upgrade their battery in future, should they wish. We also guarantee to buy a customer's car back from them in three years' time, and that's at a minimum of 50 per cent of the value of the car.

What are the greatest challenges for Tesla over the next five years?
A lot of it comes down to our own execution of following the plan and doing a good job. We're doing a lot with consumers, government and the wider industry to show our cars are more viable and better than a conventional car. The increase in consumer acceptance will grow competition and we welcome that. We are a drop in the ocean in terms of our size as an automotive company, but the pie will get bigger. National government is very excited about electric cars, we just need to ensure [that] local governments are equally [as] excited, helping us put more chargers in the street to ensure more people can feasibly drive our cars.

© Tesla

Twin-clutch gearboxes explained

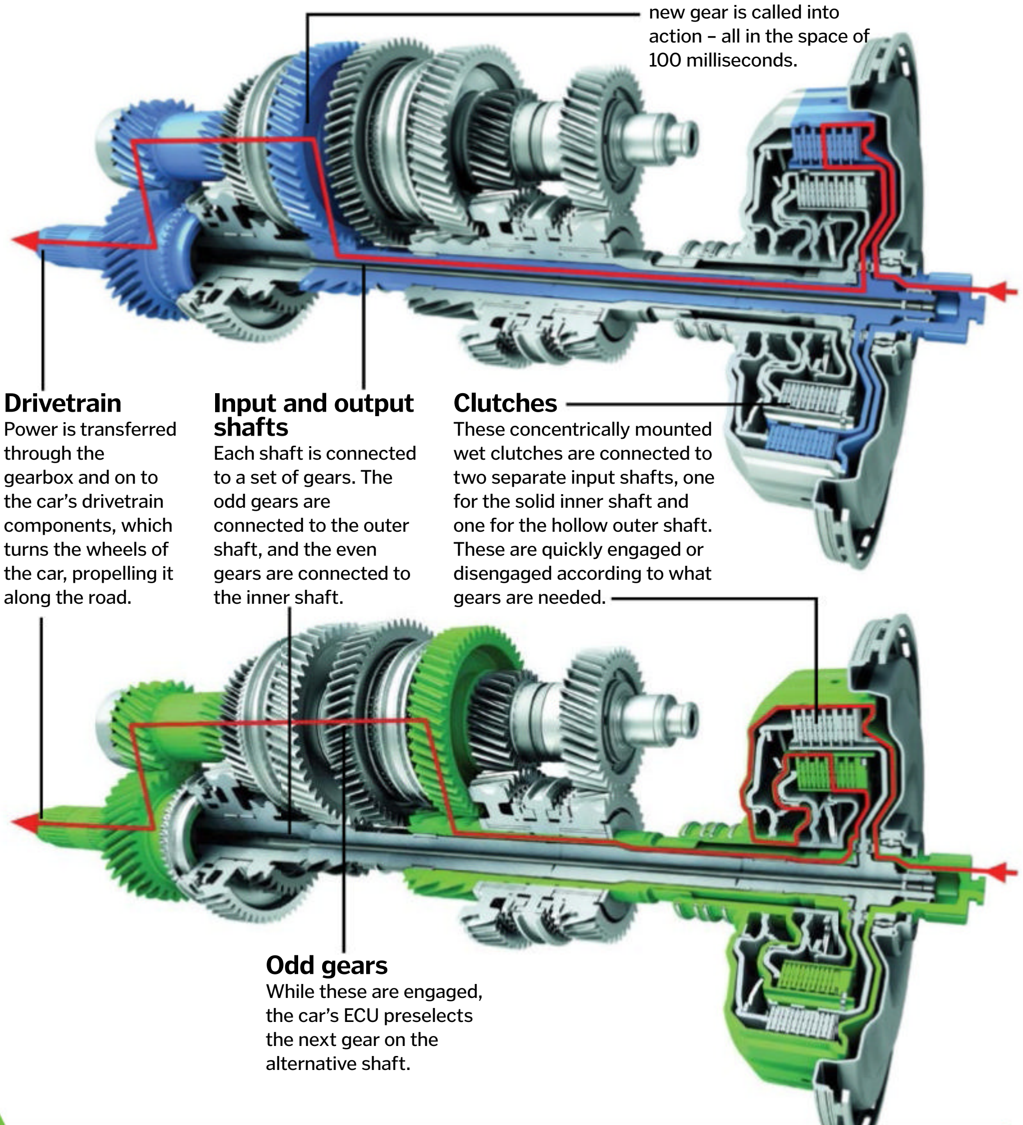
They are a common feature in today's supercars and here's why

As supercars get faster and faster, with 0-100-kilometre (0-62-mile)-per-hour times of less than three seconds, manufacturers are now looking at ways of making gains for their cars to cover even more ground in even less time. An area that has been developed a lot in supercars in recent years are gearboxes, where a lightning-quick gear change is absolutely essential if the car is to maintain linear power delivery when accelerating to 100 kilometres (62 miles) per hour and far beyond.

To provide this super-quick shift, manufactures such as Porsche, Audi and Lamborghini have produced a complex yet exquisite 'double-clutch' semi-automatic gearbox that substantially reduces the time it takes to shift up or down a gear. This technology works by effectively splitting the gearbox in two, with a concentrically mounted clutch on the end of two separate input shafts. The odd gears are on one shaft and the even gears are on the other. When a new gear is selected, the supercar's on-board computer preselects the next gear needed on the other shaft according to driving style and conditions, so when it is time to change gear, the cog in question takes mere milliseconds to engage with the drivetrain, making sure that mighty power from the engine is fed to the wheels as efficiently and quickly as possible.

Inside a twin-clutch gearbox

Here's how a twin-clutch gearbox works in a semi-automatic Porsche 911



Even gears
When the gear change happens, the clutches are quickly swapped and the new gear is called into action – all in the space of 100 milliseconds.

Drivetrain
Power is transferred through the gearbox and on to the car's drivetrain components, which turns the wheels of the car, propelling it along the road.

Input and output shafts
Each shaft is connected to a set of gears. The odd gears are connected to the outer shaft, and the even gears are connected to the inner shaft.

Clutches
These concentrically mounted wet clutches are connected to two separate input shafts, one for the solid inner shaft and one for the hollow outer shaft. These are quickly engaged or disengaged according to what gears are needed.

Odd gears
While these are engaged, the car's ECU preselects the next gear on the alternative shaft.

Automatic vs manual gearboxes

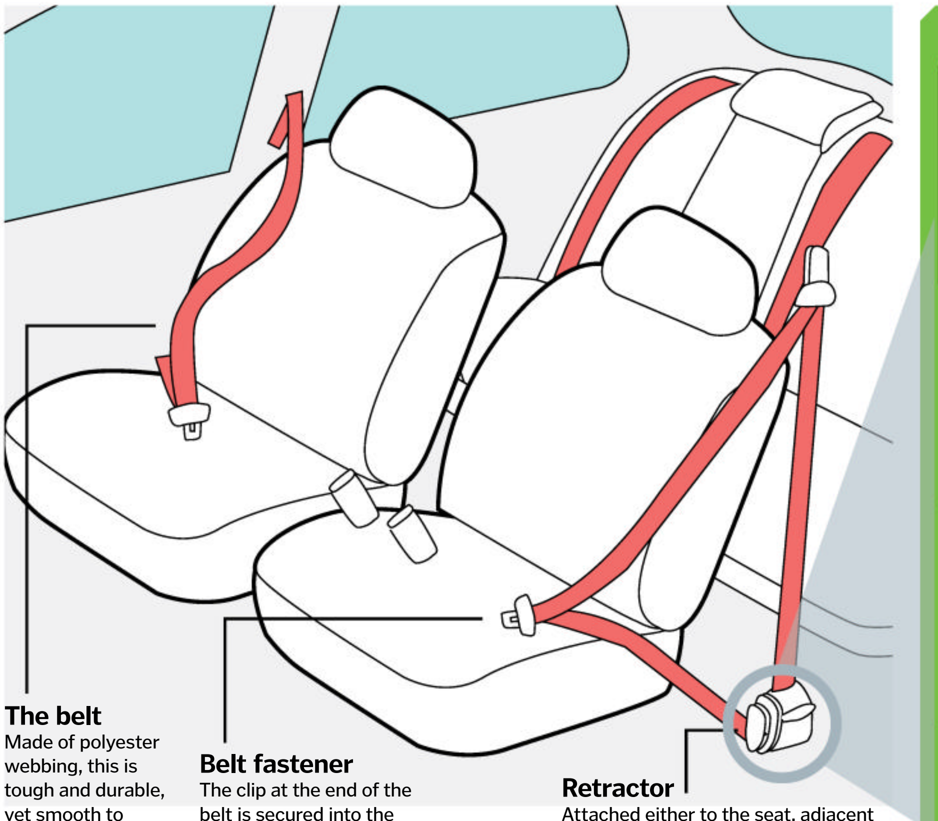
The purists will always favour the better driver involvement offered from the physical 'throw' action when changing gears with a gear stick, but the reality is that, as cars become ever faster and more powerful, automatic gearboxes are inevitably the future. The reason for this is threefold: they allow for quicker gear changes as we've just discovered, plus they're more economical as the car's on-board computer will always select new gears to keep fuel usage down, while a human can become lazy or forget to change gear according to these parameters. Then there's the safety and comfort factor: as cars produce more power, a bigger clutch is needed to transfer the power to the gearbox, which usually results in a very heavy clutch pedal on supercars. An automatic gearbox takes away the clutch pedal, meaning you can drive the car in comfort without giving your left thigh an excessive workout!

DID YOU KNOW? *The first seatbelts were invented in the early 19th Century*

How seat belts keep you safe

Here's how a safety belt works to protect you in the event of a collision

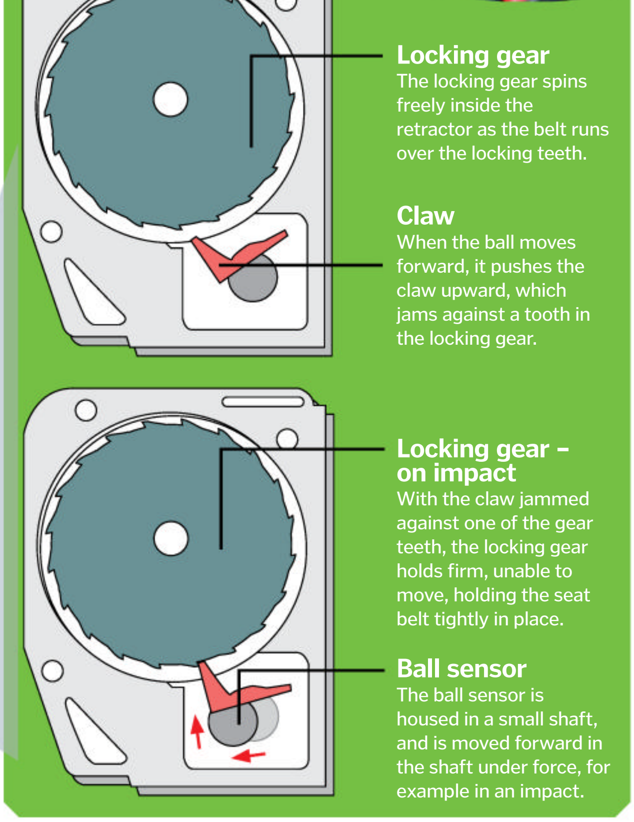
Seat belts are simple to use, relatively comfortable and extremely effective at keeping you safe



The belt
Made of polyester webbing, this is tough and durable, yet smooth to touch – crucial, as it is strapped over the torso.

Belt fastener
The clip at the end of the belt is secured into the fastener, which is attached at the bottom of the seat and holds the belt in place.

Retractor
Attached either to the seat, adjacent to the fastener, or holed in a car's B pillar, the belt runs through this mechanism that reacts in an accident.



Locking gear
The locking gear spins freely inside the retractor as the belt runs over the locking teeth.

Claw
When the ball moves forward, it pushes the claw upward, which jams against a tooth in the locking gear.

Locking gear – on impact
With the claw jammed against one of the gear teeth, the locking gear holds firm, unable to move, holding the seat belt tightly in place.

Ball sensor
The ball sensor is housed in a small shaft, and is moved forward in the shaft under force, for example in an impact.

The art of emergency vehicle lighting

Everybody recognises the blue flashing lights used by the emergency services, but do you know how they work?

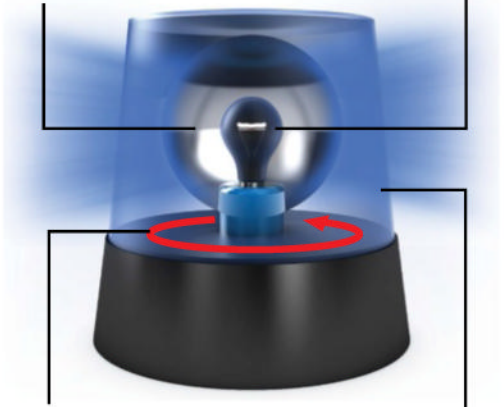
Fixed to the top of police, fire and ambulance service vehicles, flashing blue lights are deployed in the event of an emergency. Their bright flashes grab the attention of other road users from a distance, allowing them to take evasive steps in good time to make sure the emergency vehicle can pass through safely and quickly, even in heavy traffic, which is crucial when responding to an emergency call.

Although brighter, more efficient blue LED lights are now commonplace on police cars, ambulances and fire engines, the old-fashioned method of using a see-through unit with a single light bulb inside has long been a trusted ally of the emergency services – and its magic is in the illusion it creates.

Of course, bulbs can't keep flashing on and off for long periods or they'll blow, so the illusion is created by a rotating base with a vertical reflector affixed to it, moving around a fixed light bulb. The reflector redirects light outward from one side, while blocking the light out to the other. When the base is rotated fast, this creates the 'on-off' illusion of a flashing blue light atop an emergency vehicle.

Reflector
This bounces light in many directions on one side and blocks it from the other.

Bulb
The white bulb is fixed to the roof of the see-through plastic lantern.



Light base
The base of the light rotates continuously when in operation, moving the reflector around the bulb.

Lantern
Believe it or not, the bulb isn't blue. It's white, and the lantern is coloured in order to produce the bright blue light.

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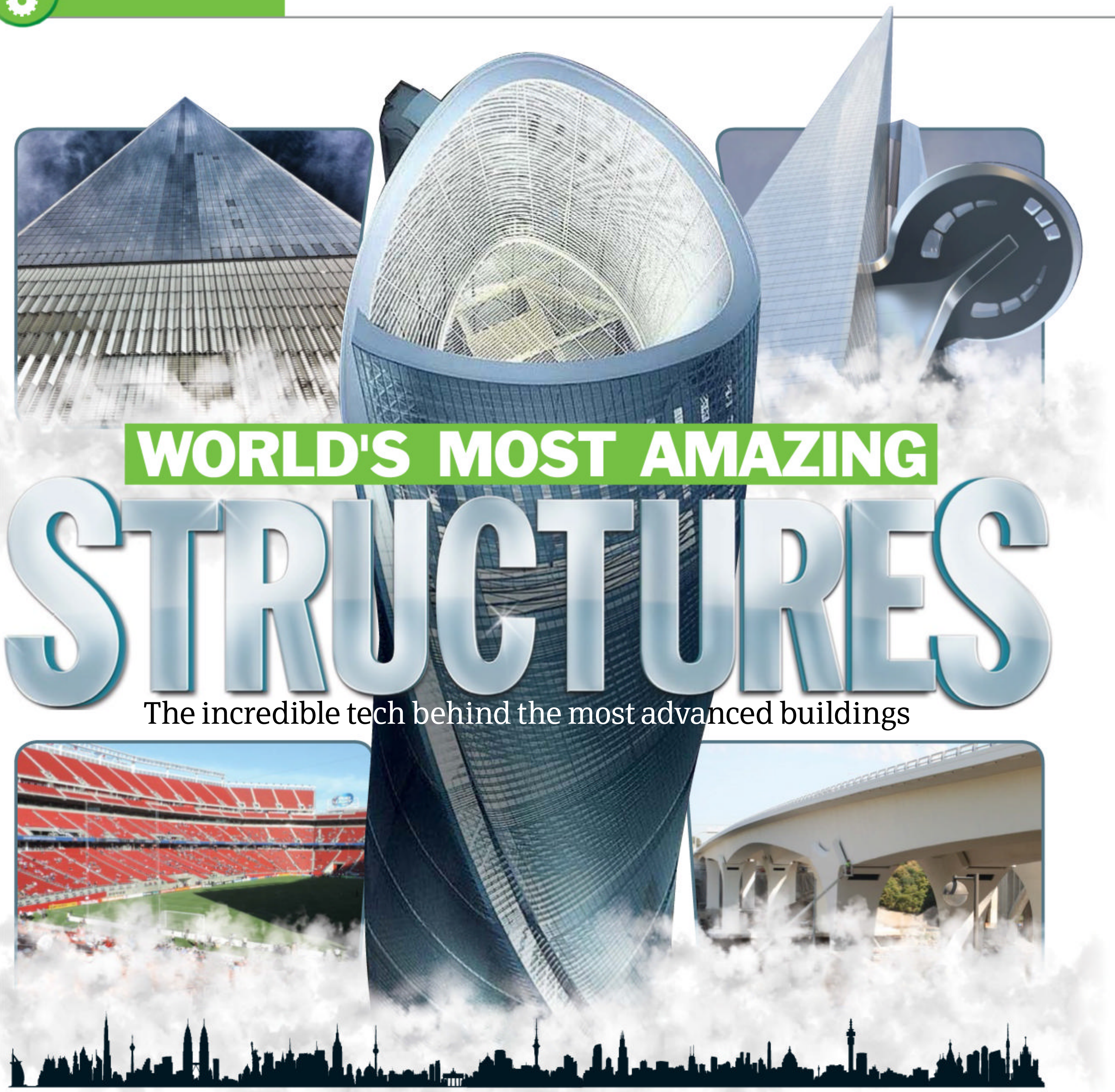
WORLD'S MOST AMAZING STRUCTURES

The incredible tech behind the most advanced buildings

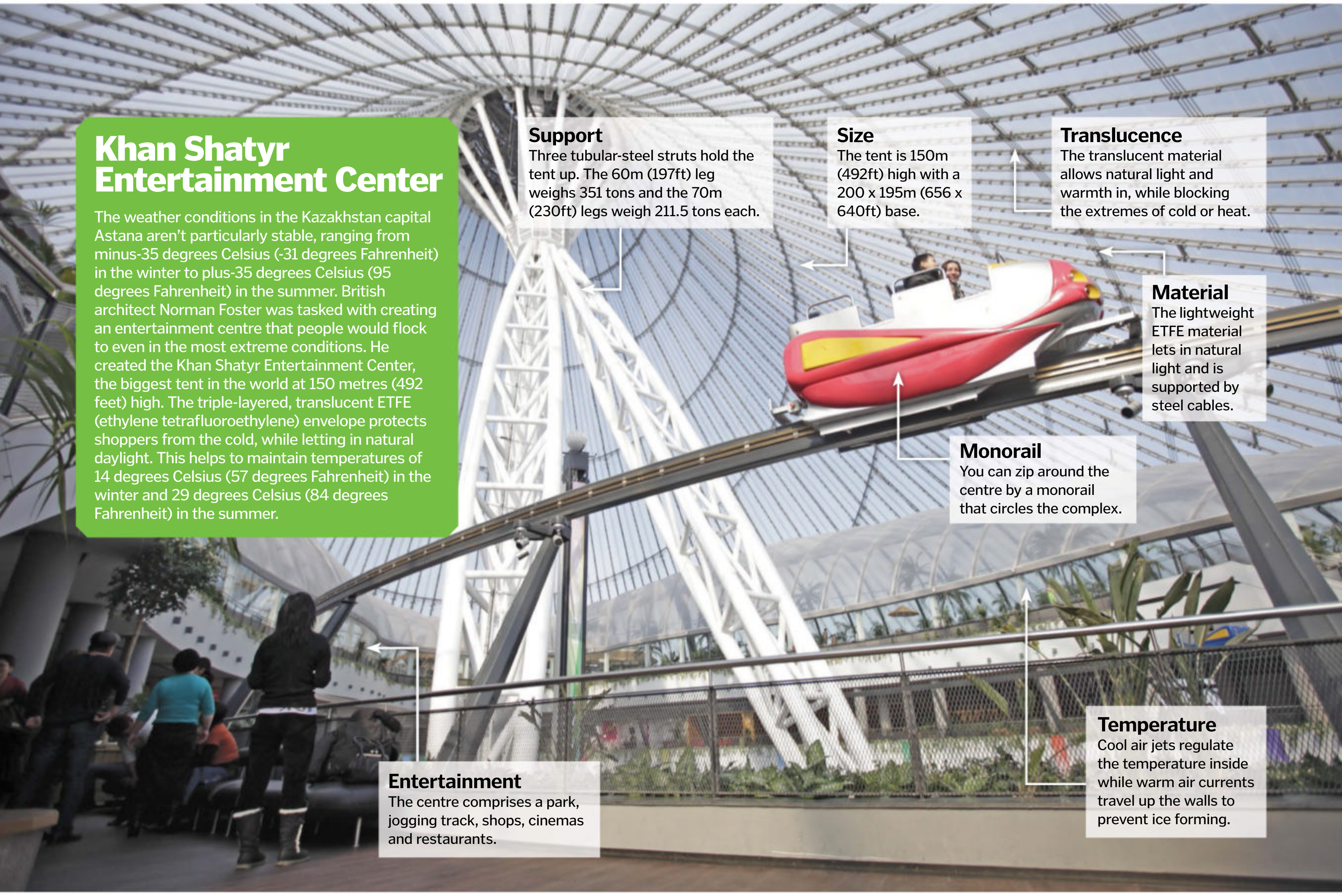


Ever since the pyramids of the Egyptians or the temples of the Greeks, humans have been racing to build bigger, better and smarter structures. However, with greater height comes greater responsibility, so the race for the skies has meant more advanced technology is required to keep the world's skyscrapers safe from winds and earthquakes.

This has led to a surge of structures modelled on a computer before a single brick or pane of glass is put in place. The technology available to designers and architects changed the design of the Sydney Opera House and showed that rotating Burj Khalifa – the world's tallest building – by 120 degrees would reduce stress from high winds. New structures are also being loaded with technology to enhance the user experience, make them more eco-friendly or relay structural information to the authorities.

From bridges to sports stadiums, technology plays an increasingly important part in building planning. The modern need for Wi-Fi connectivity and smartphone-controlled devices in the home and office has increased the challenge for architects. It is getting increasingly difficult to continue breaking the record for the world's tallest building, so the development of green technology, solar panels and other smart technology is becoming a key battleground for companies trying to design headline-grabbing structures. A mixture of necessity and posturing has accelerated the development of smart buildings, so let us take you through some of the coolest structures in the world today.

DID YOU KNOW? *St Anthony Falls Bridge was completed two months ahead of its scheduled Christmas Eve 2008 deadline*



Khan Shatyr Entertainment Center

The weather conditions in the Kazakhstan capital Astana aren't particularly stable, ranging from minus-35 degrees Celsius (-31 degrees Fahrenheit) in the winter to plus-35 degrees Celsius (95 degrees Fahrenheit) in the summer. British architect Norman Foster was tasked with creating an entertainment centre that people would flock to even in the most extreme conditions. He created the Khan Shatyr Entertainment Center, the biggest tent in the world at 150 metres (492 feet) high. The triple-layered, translucent ETFE (ethylene tetrafluoroethylene) envelope protects shoppers from the cold, while letting in natural daylight. This helps to maintain temperatures of 14 degrees Celsius (57 degrees Fahrenheit) in the winter and 29 degrees Celsius (84 degrees Fahrenheit) in the summer.

Support
Three tubular-steel struts hold the tent up. The 60m (197ft) leg weighs 351 tons and the 70m (230ft) legs weigh 211.5 tons each.

Size
The tent is 150m (492ft) high with a 200 x 195m (656 x 640ft) base.

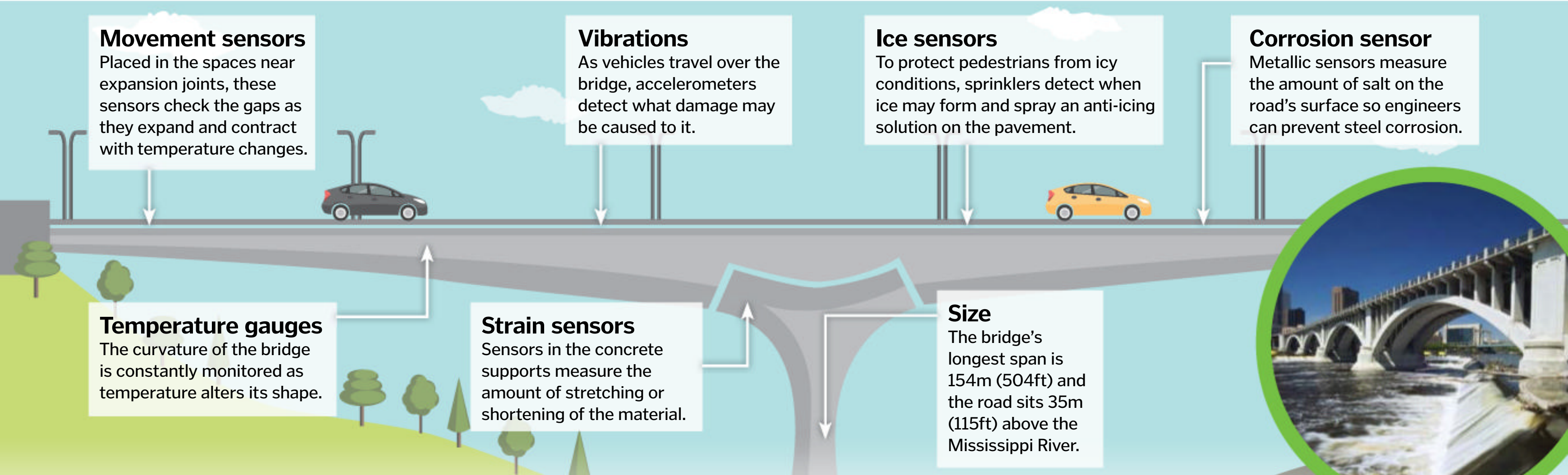
Translucence
The translucent material allows natural light and warmth in, while blocking the extremes of cold or heat.

Material
The lightweight ETFE material lets in natural light and is supported by steel cables.

Monorail
You can zip around the centre by a monorail that circles the complex.

Temperature
Cool air jets regulate the temperature inside while warm air currents travel up the walls to prevent ice forming.

Entertainment
The centre comprises a park, jogging track, shops, cinemas and restaurants.



Movement sensors
Placed in the spaces near expansion joints, these sensors check the gaps as they expand and contract with temperature changes.

Vibrations
As vehicles travel over the bridge, accelerometers detect what damage may be caused to it.

Ice sensors
To protect pedestrians from icy conditions, sprinklers detect when ice may form and spray an anti-icing solution on the pavement.

Corrosion sensor
Metallic sensors measure the amount of salt on the road's surface so engineers can prevent steel corrosion.

Temperature gauges
The curvature of the bridge is constantly monitored as temperature alters its shape.

Strain sensors
Sensors in the concrete supports measure the amount of stretching or shortening of the material.

Size
The bridge's longest span is 154m (504ft) and the road sits 35m (115ft) above the Mississippi River.

Minnesota smart bridge

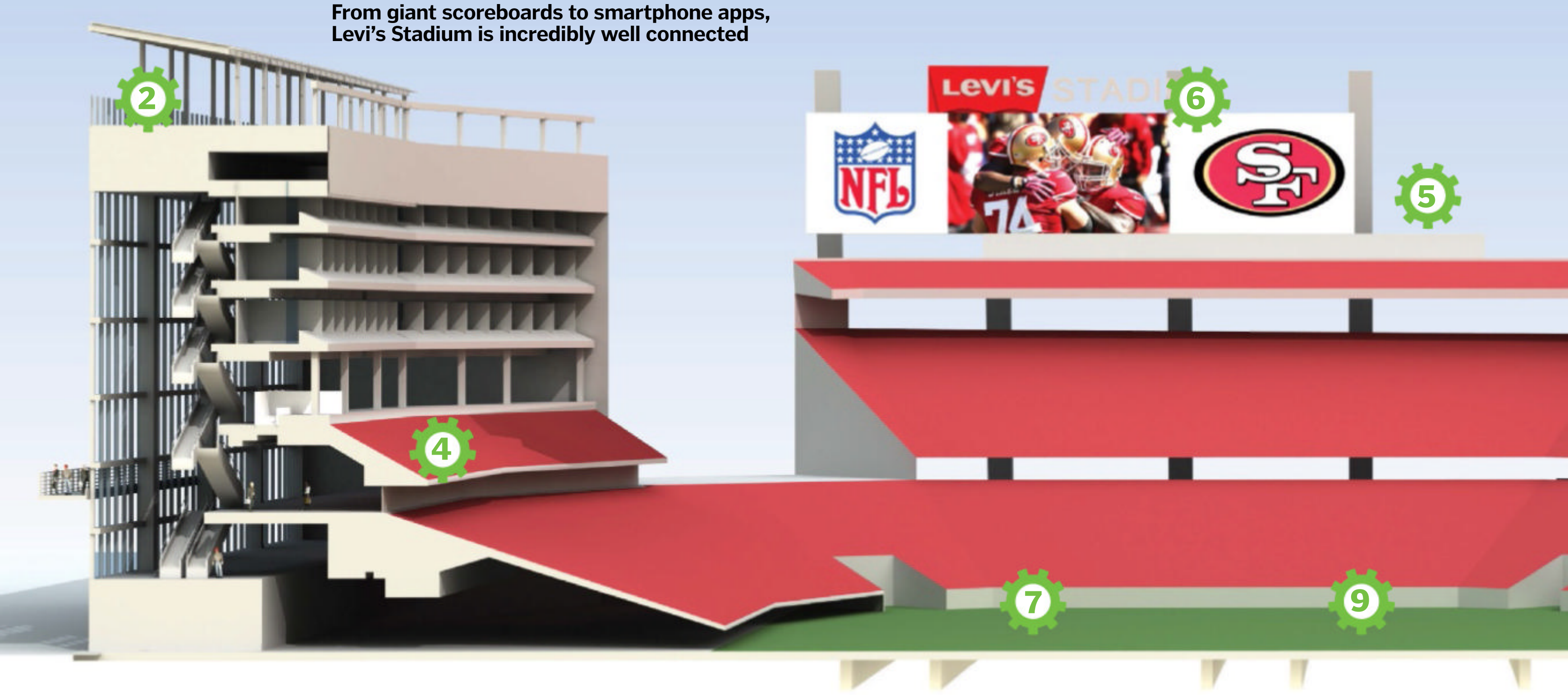
When the Mississippi River Bridge in Minneapolis, Minnesota collapsed in 2007 one of the key features of its replacement – the Saint Anthony Falls Bridge – was the ability to monitor the condition of the bridge so it could never happen again. The $234 (£150)-million bridge took under a year to complete and is now known as 'America's smartest bridge'. The 371-metre (1,216-foot)-long bridge contains a number of sensors that measure the amount of movement caused by weather, air temperature and traffic. It then transmits this data to Minnesota University. Accelerometers are also placed at the mid-point of each girder to check for excessive vibrations.

SMART STADIUMS

The rise of sport on TV and internet streaming is making it tougher for sports teams to lure fans to the stadium, but the new home of the San Francisco 49ers, the Levi's Stadium, could turn the tide. This $1.2-billion (£788-million) American football stadium is packed to the rafters with amazing technology, such as 4K TV, Wi-Fi access for all and an app that guides you to your seat. All this tech is aimed at getting fans off the sofa and to the ground by offering the multimedia experience they can enjoy at home while savouring the atmosphere live entertainment can bring.

Levi's screens

From giant scoreboards to smartphone apps, Levi's Stadium is incredibly well connected



1 Seat finder The app can detect where you are and guide you to the entrance nearest your seat.

2 Solar power 1,858m^2 (20,000ft^2) of solar panels are capable of providing the energy for all ten of the team's home games each year.

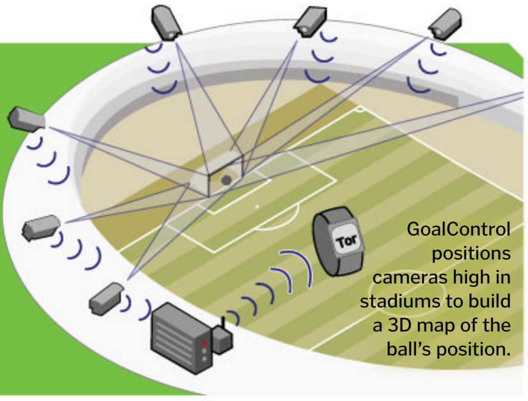
3 On the box 70 4K televisions are installed in the executive suites with a further 2,000 Sony TVs around the stadium.

4 On-the-go food You can order food via the app, which will be delivered to your seat.

5 Wi-Fi connectivity An incredible 40Gb/s of bandwidth can service speedy Wi-Fi access for 60,000 fans.

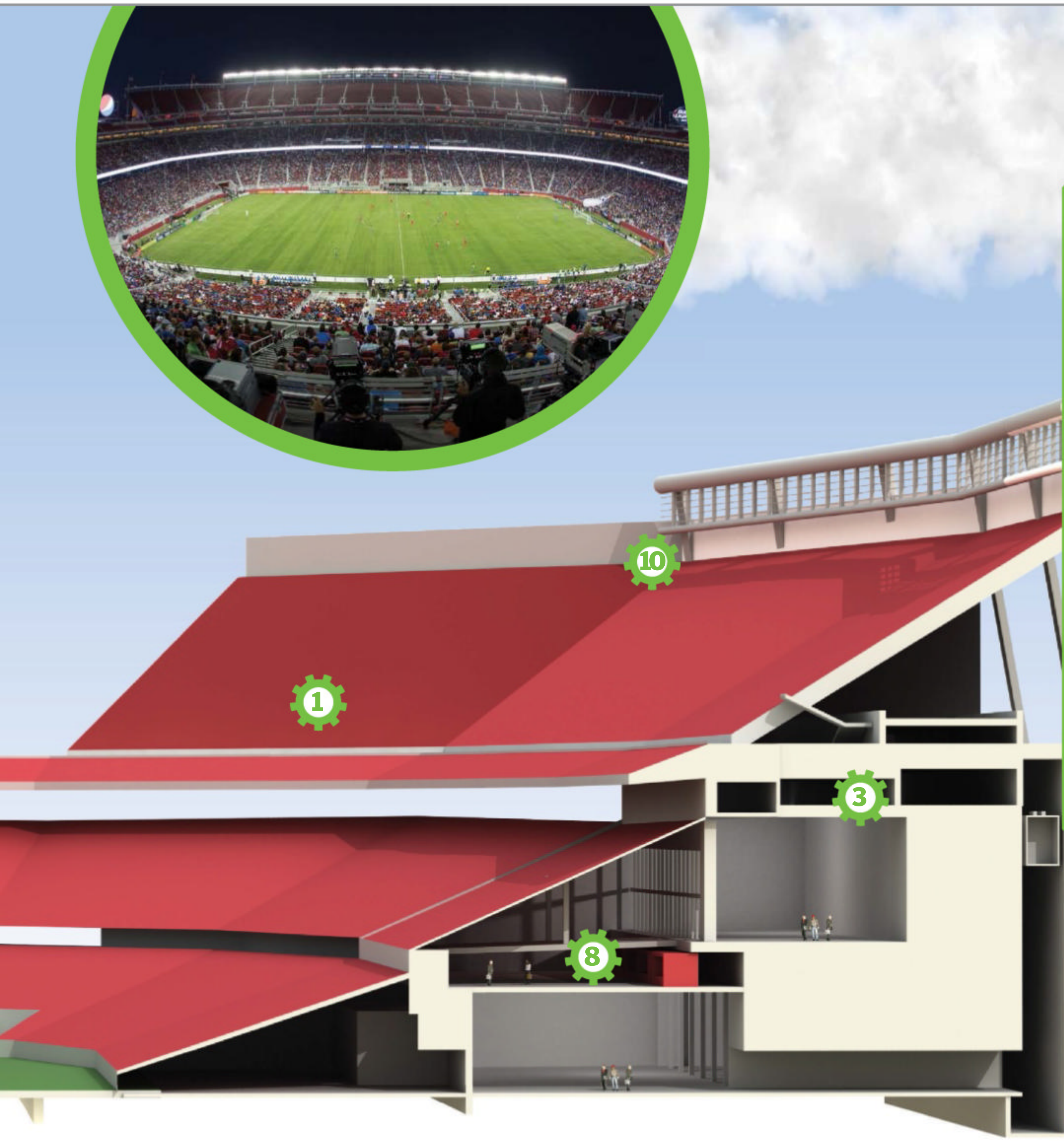
Goal-line technology

The clamour for goal-line technology in football became too loud for FIFA to ignore following the 2010 World Cup, so several methods were trialled. Hawk-Eye and GoalControl employ 14 high-speed cameras running at 500 frames per second to follow the ball all game, building up a 3D image of its position on the pitch. If the ball crosses the line a signal is sent to the referee's watch. Other systems such as Cairos GLT and GoalRef use a combination of magnetic fields and electronics. The goal is surrounded by low magnetic fields and the ball contains an electronic circuit. The ball's circuit causes a measurable change in the magnetic field when it enters the goal. Sensors detect this change and instantly alert the referee.



GoalControl positions cameras high in stadiums to build a 3D map of the ball's position.

DID YOU KNOW? *France's Karim Benzema scored the first goal-line-tech confirmed goal, at the 2014 World Cup against Honduras*



Skycam

Skycam is a Sony HDC-P1 camera hooked up to a Steadicam harness. This harness is secured by four cables that stretch to each corner of a stadium. These are manipulated to allow the camera to rise, fall, rotate 360 degrees and track the action at up to 40 kilometres (25 miles) per hour. The 23-kilogram (50 pound) device also contains an obstacle avoidance system that detects a hazard and automatically re-adjusts. It can even broadcast live action in 3D.

If there is an aerial shot of the game then chances are a Skycam took it

6 Scoreboards

The stadium has two huge LED-lit scoreboards, the larger of the two measures 61 x 14.6m (200 x 48ft).

7 Instant replays

If you've missed anything you can get instant replays on your phone.

8 Bathrooms breaks

The app also helps you find the food stands and bathrooms with the shortest queues.

9 Eco-grass

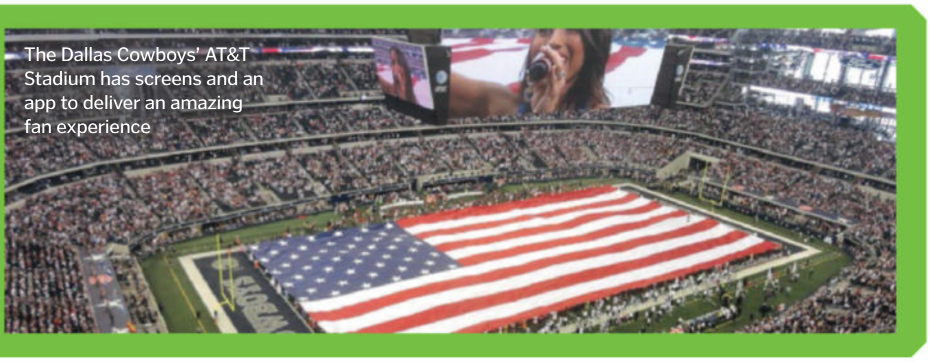
The Bermuda Bandera grass uses 50 per cent less water than normal grass.

10 Access points

There are 1,500 internet access points in the stadium, more than double than the amount at last year's Super Bowl venue.

Appy and you know it

Stadiums are starting to use apps to enhance the fans' experience. The Levi's Stadium app allows fans to order food and drink, find seats and toilets and watch instant replays. The Wembley Stadium app displays the view from a particular seat before the ticket is bought and features a travel planner. The Dallas Cowboys have gone for the entertainment angle, using the Wi-Fi connection to sync up all users' smartphones and create a light show.



The Dallas Cowboys' AT&T Stadium has screens and an app to deliver an amazing fan experience

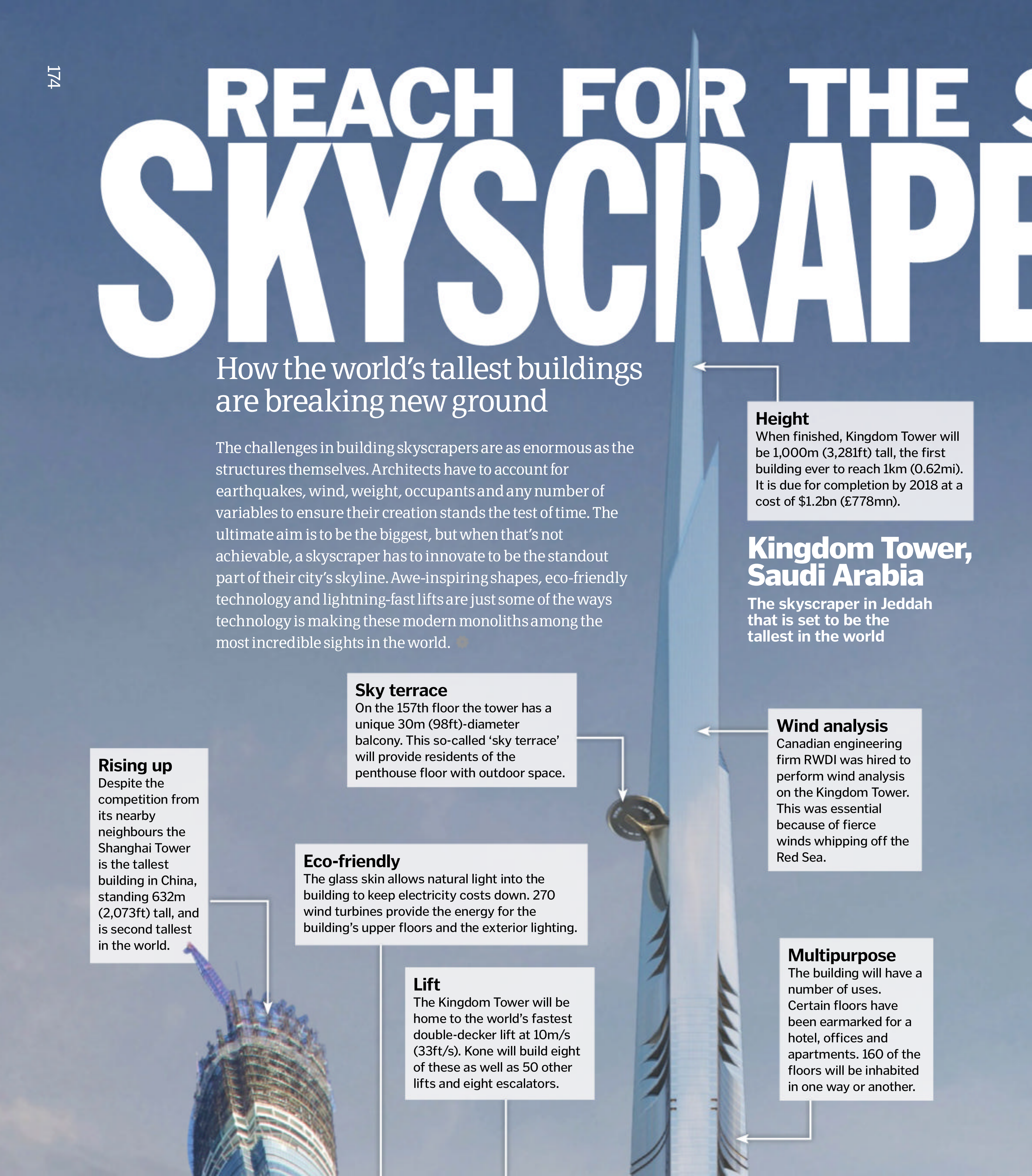
REACH FOR THE SKY SKYSCRAPERS

How the world's tallest buildings are breaking new ground

The challenges in building skyscrapers are as enormous as the structures themselves. Architects have to account for earthquakes, wind, weight, occupants and any number of variables to ensure their creation stands the test of time. The ultimate aim is to be the biggest, but when that's not achievable, a skyscraper has to innovate to be the standout part of their city's skyline. Awe-inspiring shapes, eco-friendly technology and lightning-fast lifts are just some of the ways technology is making these modern monoliths among the most incredible sights in the world.

Kingdom Tower, Saudi Arabia

The skyscraper in Jeddah that is set to be the tallest in the world



Height
When finished, Kingdom Tower will be 1,000m (3,281ft) tall, the first building ever to reach 1km (0.62mi). It is due for completion by 2018 at a cost of $1.2bn (£778mn).

Sky terrace
On the 157th floor the tower has a unique 30m (98ft)-diameter balcony. This so-called 'sky terrace' will provide residents of the penthouse floor with outdoor space.

Wind analysis
Canadian engineering firm RWDI was hired to perform wind analysis on the Kingdom Tower. This was essential because of fierce winds whipping off the Red Sea.

Rising up
Despite the competition from its nearby neighbours the Shanghai Tower is the tallest building in China, standing 632m (2,073ft) tall, and is second tallest in the world.

Eco-friendly
The glass skin allows natural light into the building to keep electricity costs down. 270 wind turbines provide the energy for the building's upper floors and the exterior lighting.

Lift
The Kingdom Tower will be home to the world's fastest double-decker lift at 10m/s (33ft/s). Kone will build eight of these as well as 50 other lifts and eight escalators.

Multipurpose
The building will have a number of uses. Certain floors have been earmarked for a hotel, offices and apartments. 160 of the floors will be inhabited in one way or another.

Keeping still

A major consideration in the construction process for buildings in areas prone to earthquakes is how to make sure they stay standing. The Taipei 101 skyscraper in Taiwan has a 730-ton ball hanging from its roof which swings slightly when the building starts to shake, counteracting any movement and drastically reducing the amount of sway. Other buildings such as the Utah State Capitol (below) use a different system known as base isolation. Almost 300 rubber-topped isolator devices are installed under the floor of the Capitol, acting like a suspension system to keep the building stable during strong seismic events.

Shanghai Tower

China's tallest building, despite some close competition

Shaping

The impressive shape of the tower is a practical decision. The curved corners and asymmetrical design reduce the wind effect by 24 per cent, saving $58m (£38m) in material costs.

Construction

The centre of the tower is a 27 x 27m (90 x 90ft) concrete core, supported by a cable-and-ring system. Builders used lasers on neighbouring buildings to make sure it was accurate.

Giants of the sky

The Shanghai Tower is the tallest of three gigantic structures in the city's Pudong district. Jin Mao Tower is 421m (1,380ft) and Shanghai World Financial Centre is 492m (1,614ft).

Foundations

German company Bauer laid the foundations for the Kingdom Tower in 2013, installing 72 piles 110m (361ft) deep, 44 piles 50m (164ft) deep and a further 154 at various depths.

One World Trade Center

The latest icon of New York's skyline is technologically and visually incredible

Symbolic height

One World Trade Center's 541m (1,776ft) height represents the year in which the country achieved independence (1776). It is the tallest building in the western hemisphere and the fourth tallest in the world.

Internal structure

153,000m^3 (5,403mn ft^3) of concrete was used. The base was made from iCrete, a concrete mix capable of withstanding 14,000psi of force, three times more than other current skyscrapers.

Materials

More than 45,000 tons of steel were used for the structure in providing a rigid beam-and-column frame.

Lift off

The 73 lifts are positioned in the middle of the building. They travel at 10m/s (33ft/s) so it only takes a minute to travel from the ground floor to the observation deck.

Floor space

The 109 floors are split into 19 for the base, 68 for offices, 14 for mechanical purposes, four for public space and four for the basement. There are 325,160m^2 (3.5mn ft^2) of floor space.

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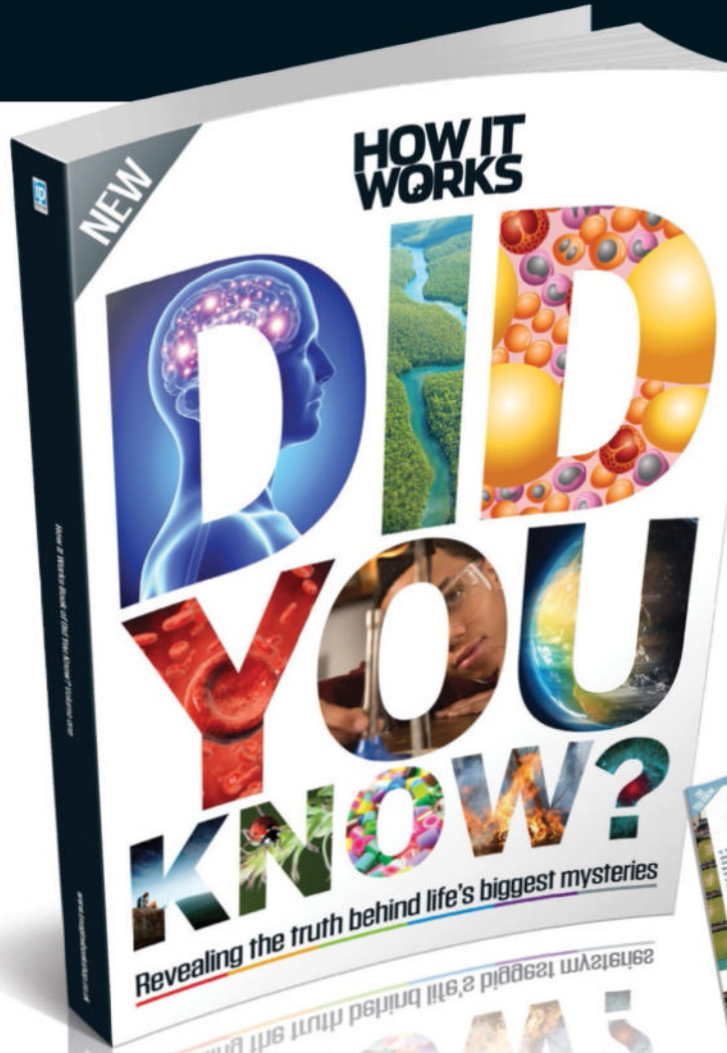
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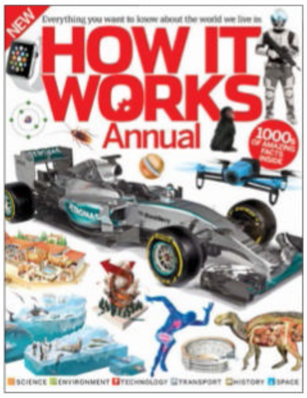
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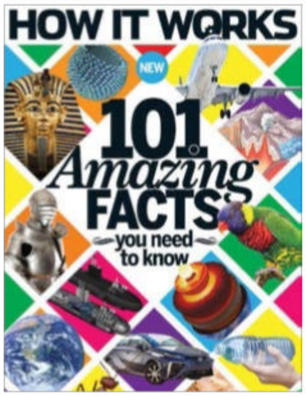
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